Bristol Water Plc

Adapting to Climate Change

FINAL DOCUMENT V1 **FEBRURY 2011**

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APPENDICES

Section 1. Executive Summary

Bristol Water has successfully delivered a safe, reliable and affordable supply of drinking water to customers within our supply area for the past 160 years.

Our primary function is as a public water supply company. We collect and store raw water from a variety of water resources, 85% from rivers and reservoirs, the remainder from groundwater. A range of treatment works from the simple to highly complex produce potable water to standards required by the Drinking Water Inspectorate (DWI). We distribute the potable water to customers via a 6000 Km mains network that includes treated water service reservoirs and intermediate pumping stations. Wessex Water undertake sewage collection and treatment functions in our area of supply.

We serve a population of approximately 1.1 million people and associated businesses in an area of 1000 square miles. This area extends from Tetbury in the north, to Glastonbury in the south and from Weston super Mare in the west to Frome in the east. We also provide a bulk water supply to the city of Bath for Wessex Water.

Regional water resources are relatively scarce. Half of the water we supply comes from central Wales via the River Severn and the Gloucester Sharpness canal, operated by British Waterways. A third of the available water is from impounding reservoirs in the Mendip Hills and the remainder from minor wells and springs.

We have sufficient resources to supply an average daily demand for water of about 300 million litres. As part of our statutory planning we also allow a safety margin of available water to meet short-term increased demand demands during dry weather and other eventualities.

As a business risk, the total impact of climate change has been ranked fifth out of a broader range of potentially damaging issues highlighted in the company risk register. This is mainly due to a large residual risk element due to uncertainty of scale and timing of climate change effects. Our analysis indicates that other financial, regulatory and supply chain business risks have a greater potential for short-term negative consequences than the generalised impact of climate change alone over the next 30 years. At present cold and freezing winters have a much more serious impact on the business and customers than high summer temperatures (in terms of asset failures and loss of customer service).

In our Water Resources Management Plan (WRMP), we have set out in detail the impact of climate change on our business over the next 25 years. The plan indicates the negative effect on customer's level of service if no action was taken to deal with climate change and other long-term changes. The adaptation plan to restore and maintain an adequate supply demand balance is set out. This takes the form of a defined basket of measures selected from a wide-ranging set of possible solutions. The preferred planning measures have been selected using an industry standard 'least cost' analysis methodology agreed with Ofwat and the Environment Agency.

We already operate a system that has a considerable degree of inbuilt resilience. Managing risks that could arise from the impact of severe weather events is a key part of our operational strategy. We understand that climate change may cause some increases in frequency and magnitude of these events as well as wider impacts on the environment and society. Over time these changes may cause reduction of service levels to customers and increased business and customer costs, if not anticipated and managed.

We have ranked the strategic areas of our business that we consider could be affected most by the effect of climate change in our supply area. In order of magnitude of business the impacts are set out below:

- The reduction of water resource availability due to the projected combination of decreasing rainfall and higher temperature combined with increased water consumption.

- The reduction of water resources availability due to a regulatory requirement to make more water available for environmental improvements through reduction of statutory licences.

- The impact of extreme events on the operation and yield of impounding reservoirs as they affect potential for failure, flooding and resource yield.

- The impact of extreme rainfall events on raw water quality and treatment processes.

- The impact of pluvial, fluvial and marine flooding generally on treatment works and other critical assets.

- The effect of higher temperatures on raw water quality and treatment processes.

- The effect of high temperatures on pumping plant, mains networks and water quality within mains networks.

- The potential impact of high temperatures, rainfall and flooding on third party suppliers, staff and general company operations.

- The potential impact of projected permanent sea level rise on critical assets

Our risk analysis indicates that the impact of climate change is relatively small in comparison to other issues such as population and housing growth and regulatory changes. However, we expect an impact and this is reflected in our business planning at both a strategic level and in terms of contingency planning.

One of our responses to adapting to the potential negative effects of climate change is directed at preserving the integrity and capacity of long-lived assets such as water sources, reservoirs, large mains and aqueducts. Our approach is intended to ensure that the availability of water will be sufficient to meet the changing need for water without an increasing risk of a shortfall in resources.

The second element of the adaptation response is to ensure that there is no deterioration in system resilience, so that reliability of water service can be maintained. Were we have identified that climate change may cause a significant impact we have proposed additional network resilience schemes. When completed, the proposed actions would minimise the adverse effects of climate change on customer’s access to a safe and reliable supply of water.

Section 2. Business Contingency Planning

Long term and emergency and contingency planning is covered by a variety of, internal strategic plans, statutory plans and site or event specific risk assessments. The main documents in the hierarchy of risk management with respect to climate change impacts are set below.

- An internal high level wide ranging business risk register
- Statutory Water Resources Management Plan 2009
- Strategic Direction Statement (SDS)
- The Periodic Review Final Business Plan (FBP)
- A flood risk analysis for critical installations
- A dam break and overflow risk analysis

These documents incorporate a significant element of both baseline and long term climate change risk planning. The links with long-term climate change is more formally expressed in some documents than others.

2.1 Business Risk Register

The Business Risk Register is a strategic-level internal document documenting a range of financial, operational, regulatory, environmental and security risks. In some instances site-specific risks are also recorded when an individual asset is of particular importance e.g. flooding risks to critical plant or loss of supply of critical chemicals. Climate change is included in this high level document with an impact score that ranks the potential business impacts as fifth only to financial failure, regulatory issues and health pandemic.

The Business Risk Register in maintained by the Director of Risk whose role includes:

- Managing the enterprise risk management system and external audits of the total risk management system.

- Reporting risk position at Board level to the biennial Executive Risk Group and annually to the internal Audit Committee.

- Ensuring Executive and Non-Executive Directors are aware of the company's top risks.

- Identifying the link between identified risks and investment requirement for business resilience plans.

Although clearly identified risks are scored in the register, this is intended to be a short-term analysis and is reviewed every year to capture emerging risks and reassess existing risks. The detailed analysis of long-term risks such as climate change takes place outside of the register in plans and processes identified later in this section.

2.2 Water Resource Management Plan

Our Water Resources Management Plan (WRMP) was prepared for the Environment Agency as part of the AMP5 Periodic Review and submitted to DEFRA in 2009. This statutory document covers the period 2010 to 2035 and sets out in detail the issues impacting the availability of water and the demand for water in that period, together with actions to mitigate adverse impacts. The WRMP is a long-term component of business planning informing the Strategic Business Plan and

5 yearly investment cycle. The WRMP analysis sets out a 25-year projection of the supply/demand position taking into account the impact of a basket of risks as set out below:

- Impact of UKCP02 climate change projection on water resources
- Impact of climate change projection on water consumption
- Population and housing growth
- Commercial and economic growth
- Changes in water consumption patterns
- Impact on greenhouse gas emissions

The purpose of the analysis is to ensure there is a long-term plan in place that will maintain customer levels of service. One of the most significant parameters is the availability of water. The impact of the UKCP02 climate change projections used in our analysis forecast a reduction in availability of water over time.

The outcome of the WRMP is an investment plan comprising a basket of operating and engineering measures to maintain the supply demand/balance over time. This is to ensure that customers will not be subject to an increased risk of restrictions water use over the 25-year period. The approach analyses a wide variety of possible options and takes into account externalities such as the social and economic costs of leakage, water efficiency and greenhouse gas emissions.

We have complied with a prescribed methodology for producing the WRMP. The Environment Agency has set out the methodology for the analysis of climate change, the consideration of future consumption and overarching approach. Ofwat has set out economic parameters such as the social and economic level of leakage and the economic method to balance supply and demand. DEFRA has set out the level of public consultation required and has controlling oversight of the plan through such directions as may be issued by the Secretary of State.

The performance of the company in respect of its WRMP is monitored annually through the regulatory June Return process. This is to ensure that outcomes from the agreed investment programme set out in the Final Business Plan are delivered and are providing customer benefits. The statutory annual update also records any material changes in outturns or assumptions that may affect the WRMP. The statutory process for producing a WRMP is repeated every 5 years as part of the business planning process and Periodic Review.

2.3 Strategic Direction Statement

Every 5 years, the company reviews its operation in the light of changing customer, regulatory, strategic or operational experience. The result of this review is to produce a high-level public consultation document, the Strategic Direction Statement (SDS). In the SDS, the company sets out the main challenges and issues affecting water supply for customers and other stakeholders over the long-term. These include the issues set out below:

- Understanding the impact of government and EU policy
- The investment requirements to maintain ageing assets
- The impact of climate change
- The effect of high levels of population and housing growth
- Maintaining flexibility, increasing resilience and security
- Improving service and quality while avoiding excessive price rises

The purpose of the SDS consultation is to inform the business planning process with stakeholder views, providing a fully costed and acceptable business plan detailing investment over a 5-year period, consistent with longer-term plans. Ofwat challenges the business plan proposals as part of the Periodic Review. The end result is a Final Business Plan (FBP) setting out the agreed short-term capital investment programme and defined customer benefits.

2.4 Final Business Plan

The Final Business Plan (FBP) defines the key areas of investment in the company assets over a 5-year period. This investment requirement is partially defined by the WRMP together with the SDS and is intended to be consistent over the short term with the least cost options to maintain the supply demand balance identified in the WRMP. The common areas between the plans include:

- Investment for reduction in demand from water efficiency measures
- Investment in water metering to reduce consumption
- Investment for reduction in leakage to social and economic levels
- Investment in existing resources and new resources to improve availability of water

The SBP addresses other wider business priorities including:

- Resilience and security of supply networks, pumps and reservoirs
- Resilience of treatment works and processes
- Maintenance of major structures such as dams and impounding reservoirs

Some of the thinking behind the resilience and security schemes in the FBP is driven by the need to address impacts of current probabilities of extreme meteorological events (high temperatures, flooding, and heavy rainfall, etc.). These events may also arise from future climate change. Therefore we have already proposed adaptation to some climate change risks as a consequence of our planning process. The extent to which these future events become more frequent and/or more severe or cross a management threshold is one of the key uncertainties in the current methodology.

2.5 Flood Risk Analysis

Following recommendations in the Pitt Review of flooding in 2007, we have carried out a high-level internal risk assessment of the potential impact of flooding of our critical infrastructure. This is based upon our knowledge of the level and location of key assets, proximity to fluvial or coastal flooding zones. We have used the Environment Agency flood risk mapping data and our GIS digital terrain model to inform the analysis. The basis of the high level analysis was the Environment Agency Flood Zone 3 for a 1 in 1000 year event.

The following assets were considered in detail:

- Water sources
- Treatment works
- Pumping and booster stations
- Service reservoirs

The method considers the frequency and scale of flooding with the impact of any consequent loss of the asset. Only high and medium flood risks were screened for further investigation of the effect of critical asset loss.

Where the loss of an asset is not readily mitigated by use of alternative supplies or plant, a high overall service risk was assigned. A further detailed investigation was then carried out for those sites with a high or medium service risk. This work was carried out internally and by consultants. Proposals for remedial measures were established for the two most vulnerable sites identified for implementation during AMP5.

2.6 Dam Overflow and Failure Risk Analysis

We have 14 large reservoirs that are subject the statutory requirements of the 1975 Reservoirs Act. Two of these are treated water storage reservoirs and two minor raw water storage reservoirs. The remaining ten are large raw water reservoirs, including three pump storage reservoirs, one off-line storage reservoir and six impounding reservoirs.

All structures are managed using the strict regime set out in the Reservoirs Act. We fully comply with the Act, which includes the requirements summarised below:

- Follow supervision, operating and maintenance requirement as advised by DEFRA panel supervising engineer and produce annual condition reports

- Facilitate detailed inspection of structures by DEFRA panel inspecting engineer at 10-year intervals or less if required

- Recording of water levels, depths, overflows and other discharges or incidents

- Recording of dam stability, settlement, masonry condition, cracks and leakages

- Comply with any recommendation from an engineers report

- Prepare reservoir flood plans as set out in the 2003 Water Act and amended by the Floods and Water Bill 2010

In addition to the production of reservoir flood plans we have carried out a quantitative analysis of the total risk of reservoir failure for individual and combinations of circumstances (QRA). A significant component of this analysis is the quantity of reservoir overflow that may be tolerated without initiating a reservoir failure. The analysis was carried out by external consulting engineers. It made use of the current industry standard for dam assessment, 'Interim Guide to Quantitative Risk Assessment for UK Reservoirs' (Brown and Gosden 2004).

For our category 'A' reservoirs where failure could result in loss of life, we have investigated the discharge and overflow capacity in terms of the probable maximum flood risk (PMF). This study confirmed that these structures have an acceptable or low probability of failure at a 0.5 PMF or greater (0.5 PMF estimated to have a 1 in 10,000 year return period).

Although our reservoirs are able to safely handle the 1 in 10,000 year flood discharge or greater without incurring significant risk of failure, the discharge volumes under such circumstances would be likely to cause significant damage downstream and add to problems of severe local flooding. However, in such circumstances the damage would not be compounded by the failure of a reservoir.

In order to establish the impact of climate change on this type of analysis, we would need to fully understand how the frequency or severity of such extreme events may change in future (if at all). A 1 in 100 year overflow event that changes return period to 1 in 50 years due to climate change would not have a material effect on the overall risks as analysed in the QRA.

At the current state of knowledge, the factors of safety in the QRA appear able to encompass an element of climate change risk. This could prove otherwise if it can be clearly shown that return periods of extreme events once in 10,000 years or greater are subject to order of magnitude changes.

Section 3. Climate Change Impact

Two aspects of climate change impact are considered in this section:

- Changes to temperature, rainfall, evapo-transpiration and sea level arise from present climate change projections in the southwest region.

- The effect these changes may have on the operation of the business and likely impacts for customers and other stakeholders

The greatest risk the business and our customers face is a reduction in the availability of water due to declining resources yields (i.e. a warming and drying of the region resulting in less water on the catchments).

The reasons for loss of resource yield due to climate change impacts having such high consequence are:

- There are no known readily available new water resources in our area of supply
- The loss of resource may not follow a linear or predictable pattern
- The loss of resource due to climate change may be difficult to identify
- Drought events are infrequent, and changes in long return periods difficult to identify
- Customers are reluctant to accept frequent restrictions to their use of water
- An event drier than currently planned for could result in a supply failure
- Even a partial supply failure is highly disruptive (eg. 2007 flood events at Severn Trent)
- There is a very long lead time required to develop new resources
- The cost of developing new resources (if any available) is very high

Due to the major social and economic consequences of declining availability of water, much of this report is focussed on the quantitative and qualitative analysis of this primary risk.

Other business risks are also considered, but are of an order of magnitude less than the reduction of water resources. In these cases the analysis is primarily qualitative in nature.

3.1 Climate Change projections

We have used projections of climate change produced from both UKCIP02 and UKCP09. Much of the long-term supply demand balance planning in the 2009 WRMP was based on the UKCIP02 scenarios, as this was the latest available at the time. When UKCIP09 became available we reviewed the impact at a high level on water resource yields as a comparator. However, this has been done using an interim methodology, as further work is in progress on how to best use the UKCIP09 for yield assessment.

To establish the climate change parameters affecting general business function, we have used UKCIP09 projections for temperature, rainfall and sea level corresponding to our main reservoir catchments. We have used the output from the medium emissions scenario upon which to base our future scenarios for business risk analysis.

The key climate parameters we need to consider in terms of potential business risks are:

- Mean maximum temperature of the hottest months of the year
- Changes in minimum winter temperatures
- Amount of winter rainfall
- Amount of summer rainfall
- Changes to average summer/winter temperature
- Amount of sea level rise
- Changes to frequency of extreme rainfall events
- Changes to flooding frequency
- Changes to frequency, severity or duration of drought events

The UKCIP09 data provided projections for some of these items, particularly where maximum or average impacts are concerned. The UKCIP09 output was of modest value in projecting frequency and intensity of extreme events. This would be the information of most value for risk assessment of climate change in particular:

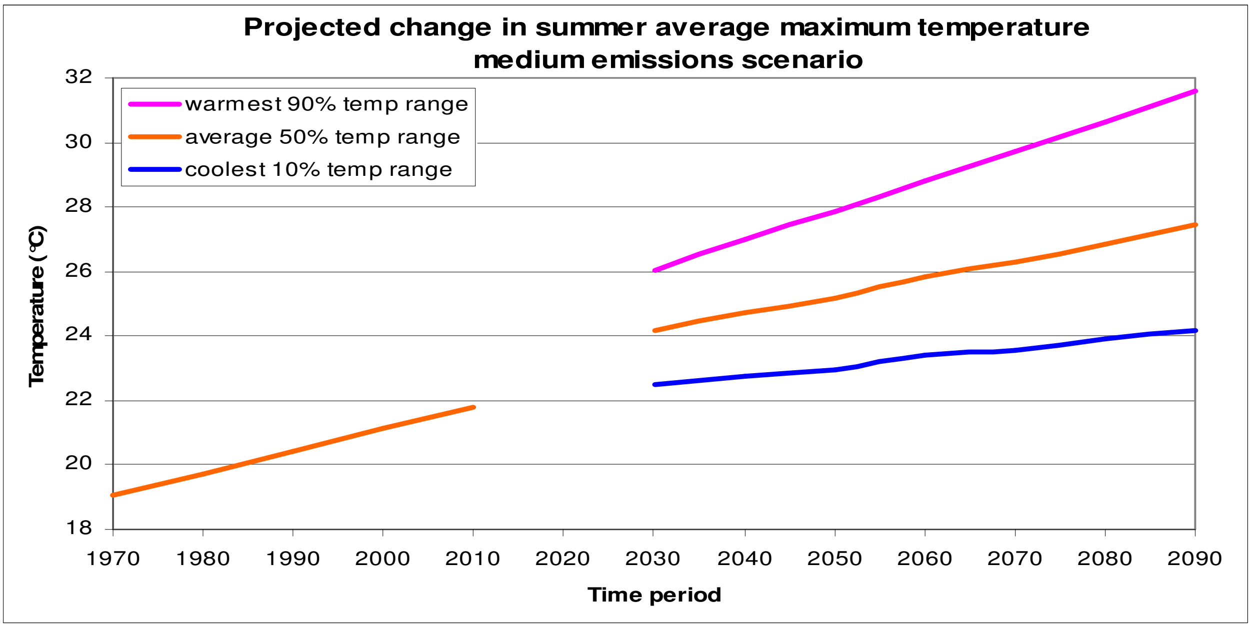
- Climate change impact on frequency of extreme rainfall events
- Climate change impact on frequency, severity or duration of drought events

The lack of definitive projections of change in these areas remains an area of uncertainty within our analysis.

We have recalculated the UKCIP09 change to climatic parameters for the southwest region and shown them as projections of absolute temperature and rainfall in the sections below. The business processes impacted by the projected changes are also summarised.

3.1.1 Summer period average daily maximum temperatures

The average of the maximum daily temperatures expected over June, July and August.



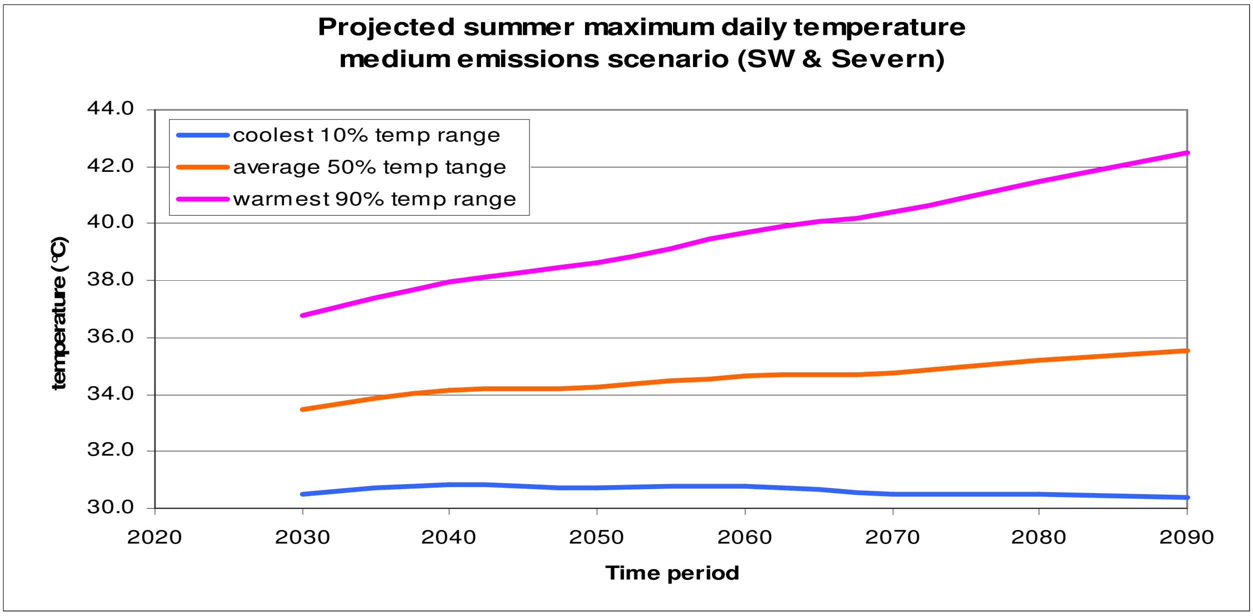
This plot shows the UKCIP09 projections for daily temperature expected the end of each decade from 2030 onwards. For comparison, the historic record for the same temperature data recorded at our Barrow Gurney weather station from the mid 1960's has been plotted. Since the 1960's the observed warming trend for summer has been approximately 0.75°C per decade.

Persistent high temperatures during a hotter than average summer already impact a range of business functions. If the projections of temperature increase are correct, by the end of 2030 the type of summer experienced in 1995 with weeks of temperatures close to 30ºC would become the norm. In a hot year the average maximum temperature over the three months of summer could be 4°C warmer by 2030 and 6°C warmer by 2050. The affected business assets and operations affected are listed below:

- Treatment works performance (filter de-oxygenation, iron and manganese releases, increased production of Bromate and THMs)
- Raw water quality (algal blooms, de-oxygenation, reduced treatability)
- Large seasonal water demand (rapid depletion of reservoirs, water quality problems)
- Increased demand for water (deteriorating supply demand balance)
- Plant operation (overheating of pumps and electronic components)
- Mains network (biofilm, poor treated water quality, taste and odour, higher chlorine requirement)
- Sustained high rates of evapotranspiration and high soil moisture deficits (resulting in delayed recharge and reservoir recovery)

3.1.2 Summer temperatures on hottest days

The UKCIP09 projection for maximum temperature likely during June, July, and August is shown below. At present, the typical hottest day summer temperatures recorded at Barrow Gurney are approximately 32°C.

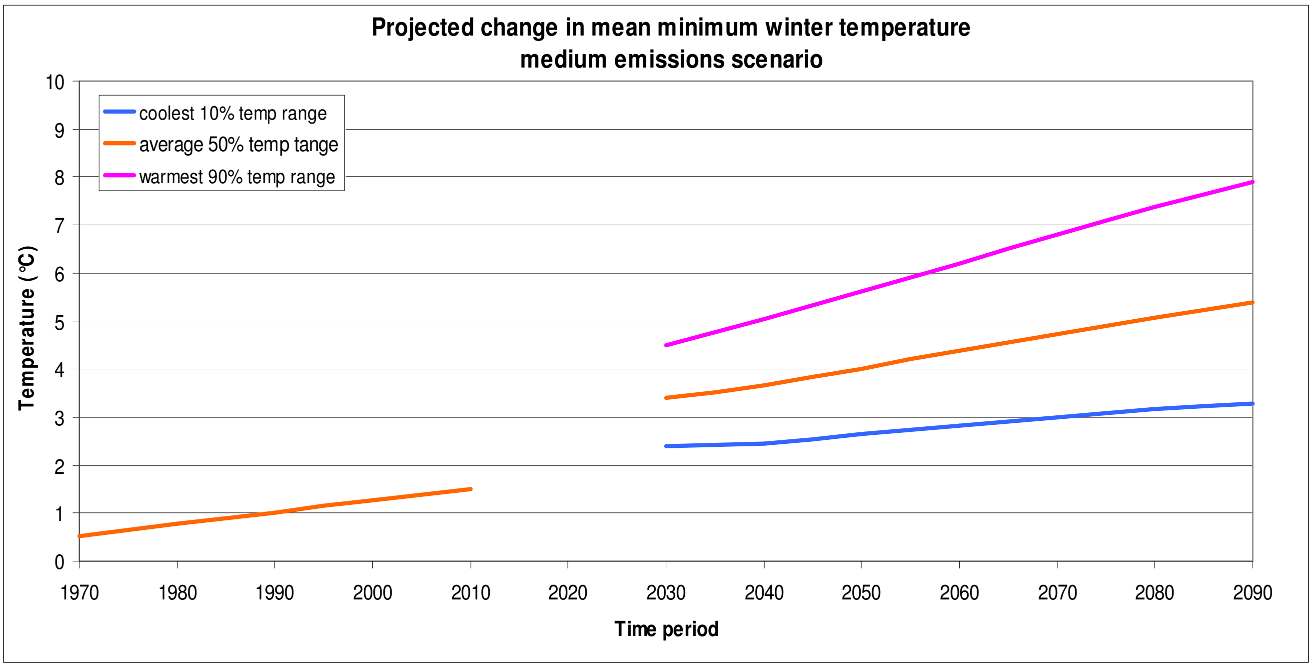


Very high daily temperatures drive high peak demands for water that can outstrip the capacity of the mains network and treatment work. Other effects are

- High peak demand for water (low system pressures or no water, inability to maintain service reservoir levels, local or partial supply failures)
- Mains network (depressurisation and poor water quality due to partially full mains)
- Network, plant and treatment works (inadequate capacity, unable to provide volumes)
- Plant operation (overheating, failure and loss of supply to service reservoirs)
- Staff welfare (heatstroke, sun burn)
- Increased water consumption per capita (deteriorating supply demand balance)

3.1.3 Winter average daily minimum temperature

The UKCIP09 projection for average minimum temperatures likely during December, January and February is shown below.



For comparison, the historic record for the same temperature data recorded at our Barrow Gurney weather station from the mid 1960's has been plotted. Since the 1960's the observed warming trend for winter has been approximately 0.25°C per decade. At present the typical average for minimum winter temperatures recorded at Barrow Gurney are approximately 2°C.

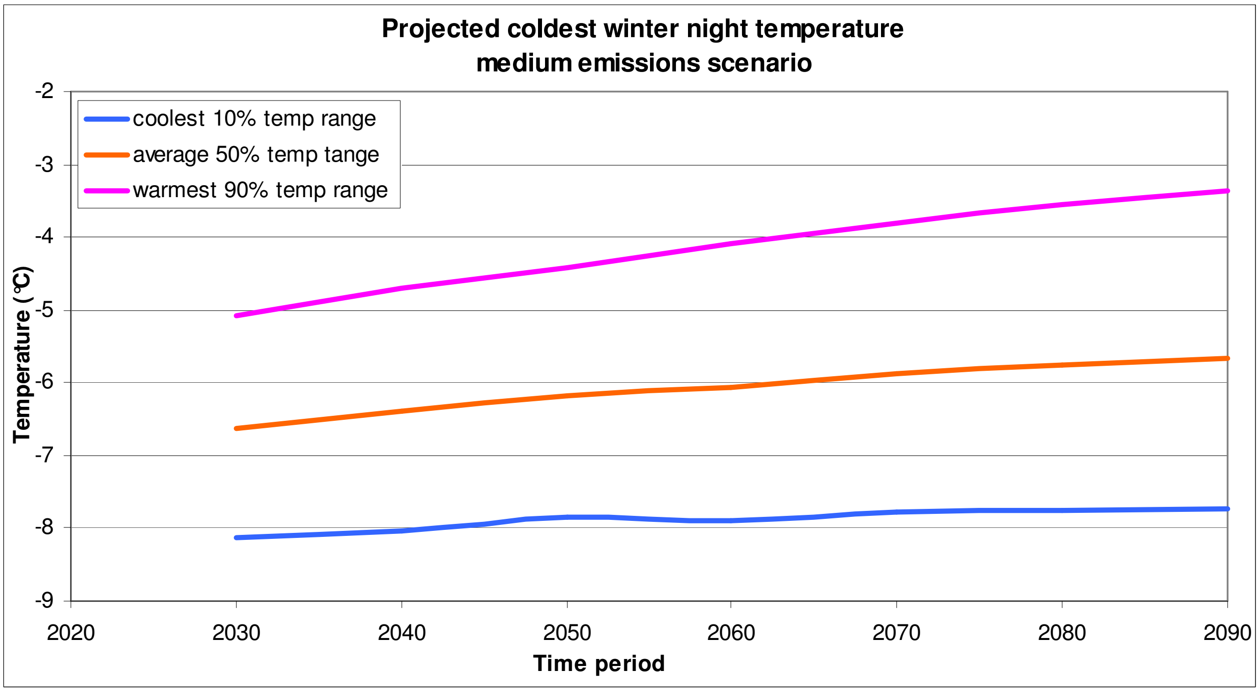
Periods of very low temperature can cause treatment works to perform poorly as the speed of chemical and biological reactions is reduced. If winters are become warmer, there may be some benefit as some treatment process become slightly more efficient.

However, warmer winters may also lead to differing cropping patterns with increasing pesticide and nutrient loading of raw waters. We already observe these effects with higher levels of nitrate and pesticides being detected in during warmer winters. These are particularly difficult contaminants to remove from water and will cause problems leading to water quality failures and increasing outage of affected sources if the currently observed contamination events become more frequent or intense.

3.1.4 Winter temperature on coldest days

The UKCIP09 projection for lowest daily temperature likely during December, January and February is shown below.

Periods of freezing weather that last for more that two or three days cause a range of problems both in the treated water network and within treatment works. At present, typical coldest day winter temperatures recorded at Barrow Gurney are approximately -8°C.



The effects of freezing weather on business operation are summarised below:

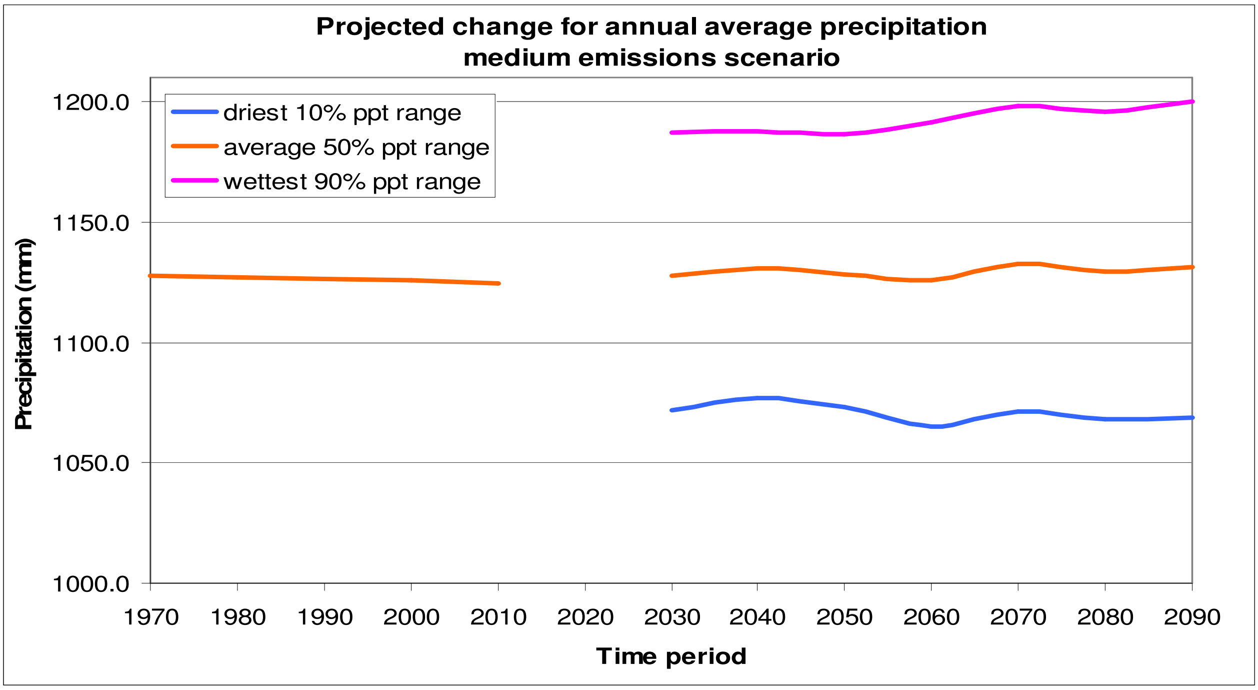
- Mains bursts (rate of failure increases by an order of magnitude)
- Leakage increases substantially (minor mains, private supply pipes and customer plumbing systems fail)
- Treatment works performance (increased level of shut downs and quality failures as dosing lines and minor pipework is blocked by ice, difficulty mixing some chemicals in freezing conditions.

From the UKCIP09 data, it is not clear whether the modest degree of winter warming predicted will be sufficient to reduce either the intensity or the frequency of freezing periods.

3.1.5 Annual average rainfall

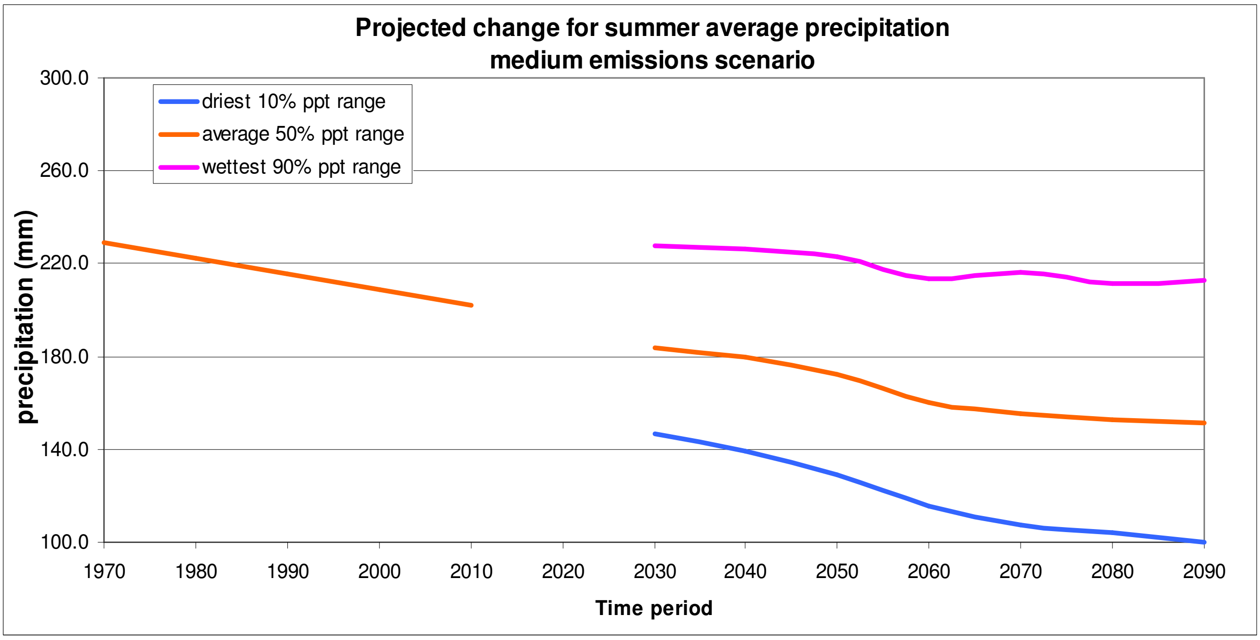
The UKCIP09 projection for the average annual rainfall for the company gauge at Litton (Mendip catchment) is shown below, together with the historic record. The historic annual average rainfall has shown a slightly decreasing trend since the 1960s. This historic decline is only of the order of 3mm in an average annual total of 1125mm and is unlikely to be significant.

The projected future trend for average rainfall at the medium emissions scenario is similar to the observed trend. The upper and lower decade percentile rainfall totals at Litton show a variation of more than 200mm from the average over the year. The years with the lowest ten-percentile rainfall totals with less than 800mm are usually, but not universally associated with water resource droughts. This indicates that the pattern of rainfall is at least as significant as the total quantity received, therefore we have considered winter and summer rainfall projections



3.1.6 Summer period average rainfall

The UKCIP09 projection for the summer average rainfall in June July and August for the company gauge at Litton (Mendip catchment) is shown below together with the historic trend. The historic annual average rainfall has shown a marked decreasing trend since the 1960s. This downward trend is very similar to the UKCP09 central estimate.



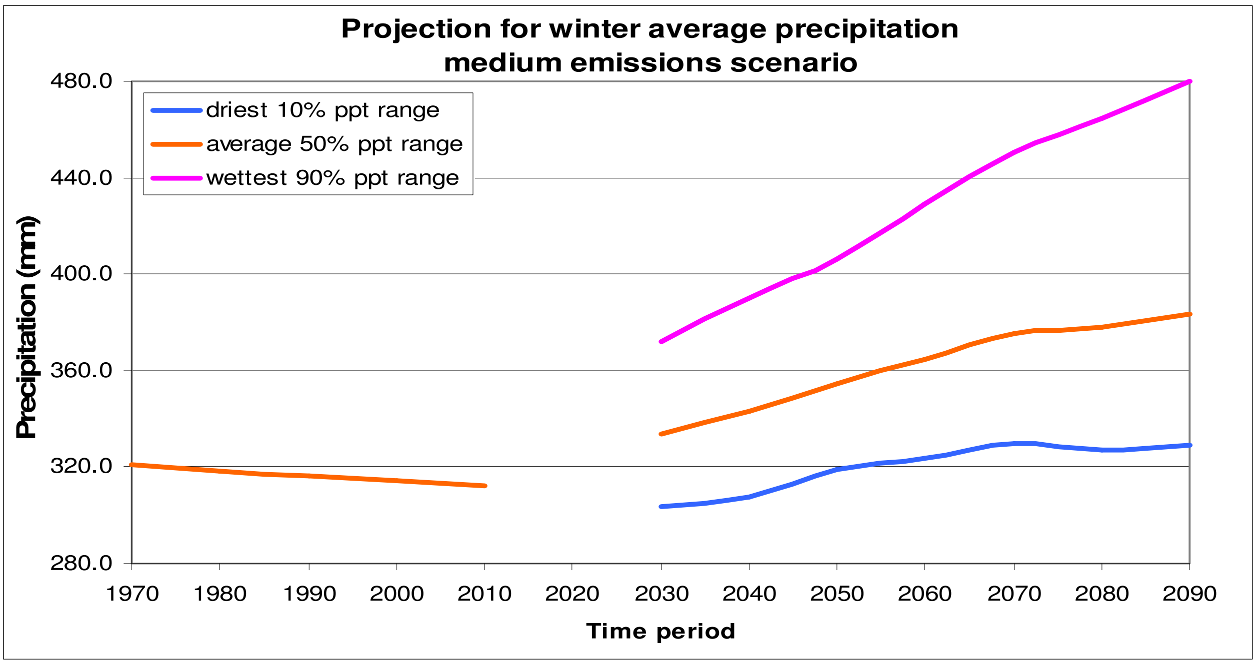
During the summer period we do not gain a significant resources benefit from average rainfall, i.e. there is rarely a significant increase in inflow to reservoirs as a result of summer rainfall. However, if rainfall during warm period does reduce the demand for water, which in turn helps to reduce the rate of reservoir drawdown. Large reductions in summer rainfall would be of concern as it could mean fewer periods of reduced water demand in summer and slightly lower water volumes in reservoirs at the end of the summer.

If the UKCIP09 projections are correct, we would expect the following:

- Additional demand for water for discretionary use during dry periods (resulting in higher per capita consumption and lower reservoir levels, impacting supply demand balance)
- Low volume in reservoirs with more frequent algal blooms (water treatment and quality issues, problems with fish kills and loss of recreational use, could compromise SSSI status and Water Framework Directive (WFD) obligations)
- Reduction in deployable output (from delayed recharge, a small effect, but could be significant long-term)
- Environmental impacts due to low river and stream flows (further regulatory reductions in abstraction to meet future Environmental obligations under the Water Framework Directive WFD)
- Increased reliance on winter rainfall and two season criticality resources (requiring a planning approach that captures as much winter water as possible)

3.1.7 Winter period average rainfall

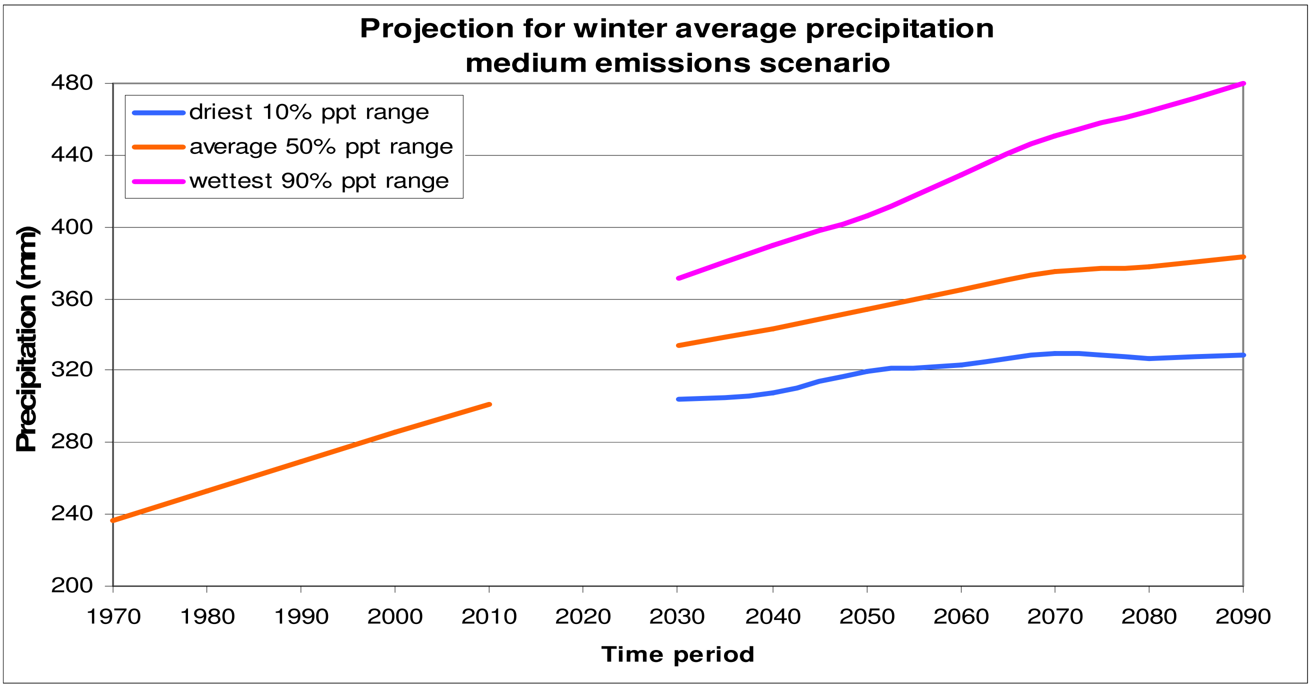
The UKCIP09 projection for the average rainfall in December, January and February for the company Litton (Mendip catchment) is shown below together with the historic trend. This gauge is considered to be more reflective of rainfall conditions affecting our three large resources reservoirs than others elsewhere in the company area.



The historic winter average rainfall has shown a decreasing trend since the 1960s. This observed downward trend is contrary to the regional UKCP09 projection. This may be a statistically insignificant effect or a local microclimate effect as the historic trend is anomalous when compared to the data at other company gauges. If the historic trend persisted into the future, eventually there could be a marked reduction in reservoir resource yield.

At our 'off catchment' gauge at Barrow Gurney, the long term rainfall record shows an increase in winter rainfall amounts over the past 50 years, very similar in rate to the projected trend for a seventy-five percentile climate change impact.

The plot below shows the historic rainfall trend at our 'off catchment' rain gauge at Barrow Gurney compared to the UKCIP09 regional projection.



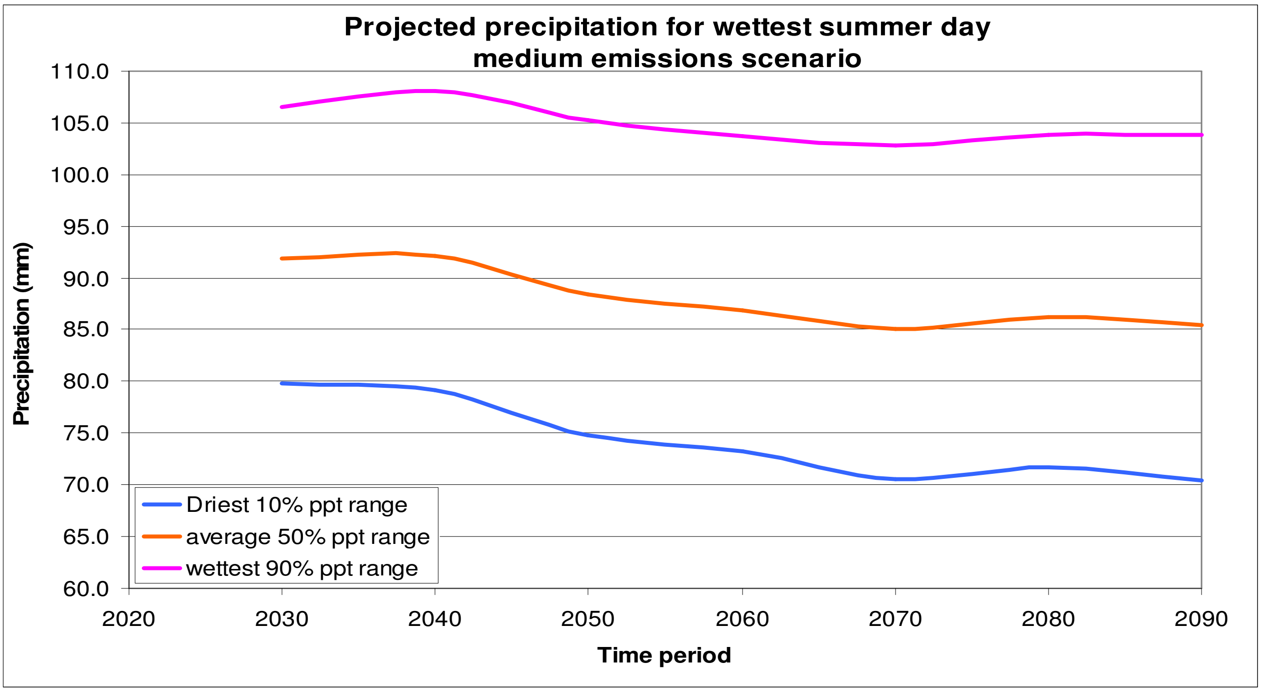
Stored water in the Mendip reservoirs provides approximately 40% of the overall resources mix. Winter rainfall is a critical factor in the recharge of the reservoirs and groundwater. At present, we consider our resources position to be two-season critical, that means security of supply is more vulnerable to dry winters than a dry summer. Increasing winter rainfall may improve the rate and scale of recharge, offsetting to some degree a propensity for drier or warmer summers. However, the increase in water consumption from population projections could mean that we become single season critical over time, making wetter winters less of a benefit.

Other impacts include:

- Large variation of inflows to reservoirs (possible stability problems with earth dams, higher rates of silt deposition)
- High volume overflows from reservoirs (down river flooding issues or damage to spillways)
- Raw water quality issues (higher leaching of nitrates phosphates and pesticides resulting in compliance outage of treatment works)

3.1.8 Wettest summer day rainfall

Incidents of local flooding are frequently associated with periods of intense rainfall within the company area of supply. The 1968 rainfall event of over 90mm within a few hours that caused much of the centre of Bristol to flood was a particularly extreme example. Fortunately, at that time the level of our largest reservoir was low and absorbed the flood inflow from the Chew catchment. Had that not been the case, the damage in the Chew valley would have been significantly worse. Intense rainfall events associated with thunderstorms appear to be more extreme in summer than the intense rainfall events during winter in our supply area. The plot below shows the UKCIP09 projected rainfall totals for summer storms based on our historic rainfall maxima.



The historic mode maximum for wet days in summer is approximately 40mm, this is unlikely to cause flooding on the scale of 1968, or issues for company assets. However, there could be significant problems for non-company infrastructure in some areas.

In general, summer storms tend to be localised and have not usually caused widespread problems even with totals above 40mm per day. The observed highest daily rainfall totals of between 70mm to 90mm have a return period of approximately once every 20 years. Our observed trend for average rainfall during summer storms has shown no significant change over the past century.

Although the UKCIP09 projections indicate that rainfall intensity may reduce in summer, the reduction does not appear to be significant in terms of the potential risk to company assets and operations from the most intense storms. The Met Office study, ‘Changes in the frequency of extreme rainfall events for selected towns and cities’ July 2010, suggests that rainfall events with present return periods of 1 in 20 years may increase in frequency to 1 in 12 years by 2040.

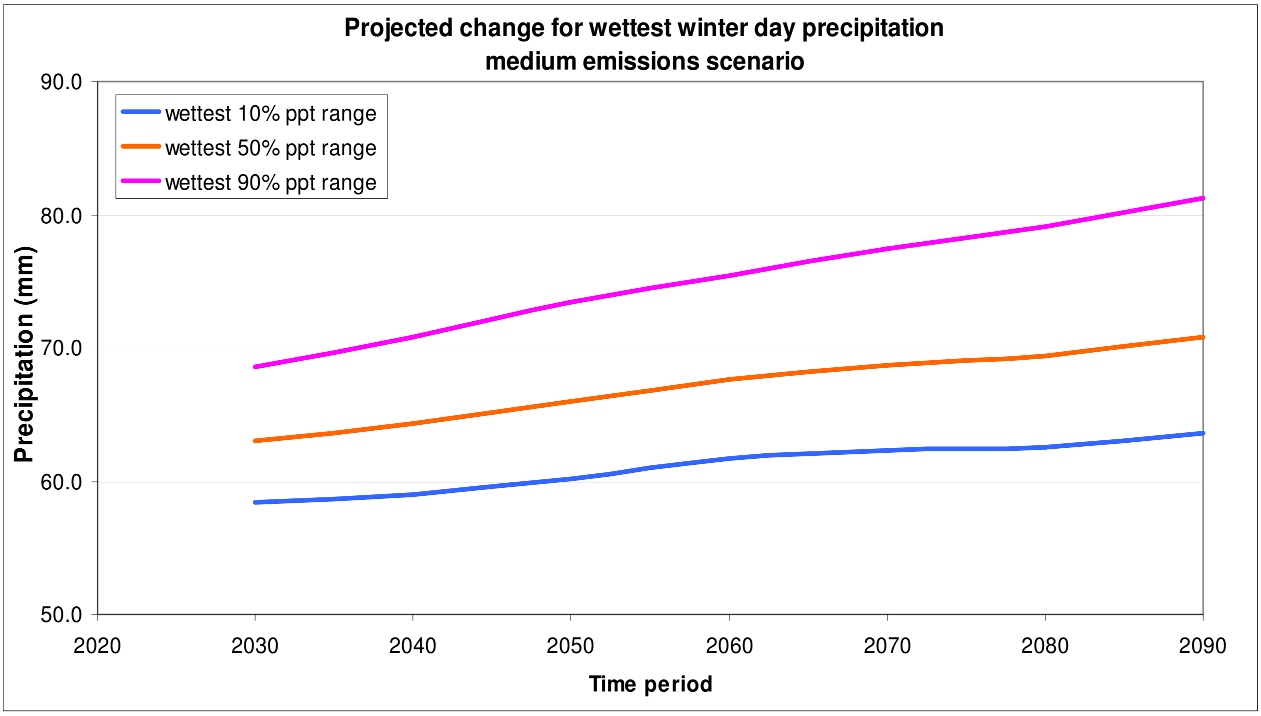
The implication is that although storm rainfall may reduce slightly in intensity, there may also be an increasing frequency of disruptive events, with potential impacts on company assets and operations as outlined below:

- High volume inflows to reservoirs (possible stability problems with earth dams, higher rates of silt deposition)

- High volume overflows from reservoirs (down river flooding issues or damage to spillways)
- Increased frequency if high turbidity in springs and wells (causing reduced treatment plant output or shutdown to maintain water quality)
- Potential flooding of critical assets (at risk sites have remedial work planned, but the solution may prove inadequate beyond 2040)
- Political pressure to maintain low reservoir levels to absorb flood inflows (if this approach was adopted, there could be substantial reductions in deployable output)
- Rapid runoff causing raw water quality (high nitrates and high pesticides concentration resulting in the need to shut down or reduce plant output)
- Increased frequency of lightning strike events associated with summer storms (causing plant, telemetry, and ICA outage)
- Local pluvial flooding (causing transportation and communication difficulties)

3.1.9 Wettest winter day rainfall

The historic mode maximum for wet days in winter is similar to those of summer at approximately 40mm. The highest observed rainfall totals are between 50mm and 70mm, less than the summer storms. This quantity of rainfall is more likely to widespread frontal rain falling onto saturated ground and under conditions when reservoirs are full. It is possible these events may be as damaging as summer storms. Observed heavy winter rain events have a return period approximately once every 15 years. The average quantity of rainfall on the wettest days of winter has shown a significantly increasing trend over the past century from 25mm to 35mm, however the trend of maximum rainfall totals do not show the same increase.



The rainfall volume on the wettest days of winter is projected to increase by up to 20% by 2080 in the worst case. This change has the potential to increase the probability of winter flooding events and large reservoir overflows. The increase in frequency from 1 in 15 years to 1 in 10 by 2080 would also be significant. The impacts outlined in the section above would potentially occur more frequently than for summer events, however the timescale available for adaptation is very long.

3.1.10 Sea level rise

The UKCIP09 projected sea level rise for the medium emissions scenario is 370mm by 2080. The company has no critical assets close to coastal regions or in areas that would be permanently affected by a one metre increase in average sea level. Additional coastal flooding and permanent flooding of some parts of our supply area may be expected. This would mean that some areas may no longer be suitable for human habitation, and therefore there would be no need for minor distribution infrastructure.

Using a 5m scenario for maximum sea level rise, some major distribution mains and parts of the domestic network may need to be moved, as they would lie under the permanently flooded areas. A permanent sea level rise of this magnitude is considered highly unlikely during the next century.

We consider the impact of sea level rise for most of the company operations and assets to be negligible, even with the impact of storm surges, compared with more general flooding risks.

Our public water supply intake from the Sharpness canal at Purton is probably the critical asset most at risk from the combined impact of coastal flooding and sea level rise. The Sharpness abstraction provides 45% of the company's water resources. If this site was likely to be incapacitated for any length of time the consequences for customers in Bristol would be relatively severe. However, there are already flood protection plans in place for this site that provides protection for the combination of sea level rise and flooding to 2035.

The Sharpness Canal is critical infrastructure that carries water from the Severn at Gloucester to Purton treatment works. From our flood risk analysis the residual flooding risk to this structure is between 1 in 100, but this decreases to 1in 50 and even 1 in 20 for some areas by 2030 with the current sea defences. Extreme fluvial and coastal flooding will cause inundation of the canal with polluted or saline water. This could mean that water supply to two major treatment works is not available for up to three weeks while the flood subsides and the canal is flushed with clean water.

An event of this magnitude would result in a loss of supply to a population of over 200,000 in the north and east of Bristol. A loss of supply on this scale for such a large population would not be manageable by the normal means of distributing bottled water or using temporary bowsers.

We plan to minimise this risk in future by increasing network resilience. This adaptation mechanism has a dual benefit as it provides improved security for other supply areas in addition to the Sharpness zone. These network resilience schemes are detailed in section 5.5 below.

The Environment Agency Shoreline Management Programme for the Severn Estuary is a critical interdependency. We recognise their continuing commitment to maintain adequate defences to protect critical assets along the Severn Estuary. This will ensure the probability of the most severe flooding remains less than 1 in 200 in any one year.

3.2 Climate change and yield of resources

The analysis of climate change in our WRMP was based on the UK Climate Change Impacts Programme (UKCIP02). This work indicated that the majority of the six global climate models used for the forecasts predict warmer and drier summers with warmer and wetter winters.

In our WRMP, climate change impacts on both water resources and consumption start from base year 2008. The scale and timing of the impacts have been calculated using the methodology set out in the Water Resource Planning Guidelines, November 2008, using the process, planning tools and spreadsheet provided in UKWIR report 06/CL/04/8. This is based upon earlier studies for UKWIR carried out by Reynard and Young and Arnell. We have used the 5^{th} and 95^{th} percentiles for run-off variation as generated by the modeling spreadsheet methodology provided for UKWIR 06/CL/04/8.

In all of the other aspects of our water resources planning we have followed the regulatory guidance set out below.

Environment Agency

- Water Resources Planning Guideline 2008
- Water Company Drought Plan guideline 2003

Ofwat

- PR09 Company Guidance and Reporting Requirements
- Changes in Frequency of Extreme Rainfall Events (UK Met Office)
- Sundry other guidance

DEFRA

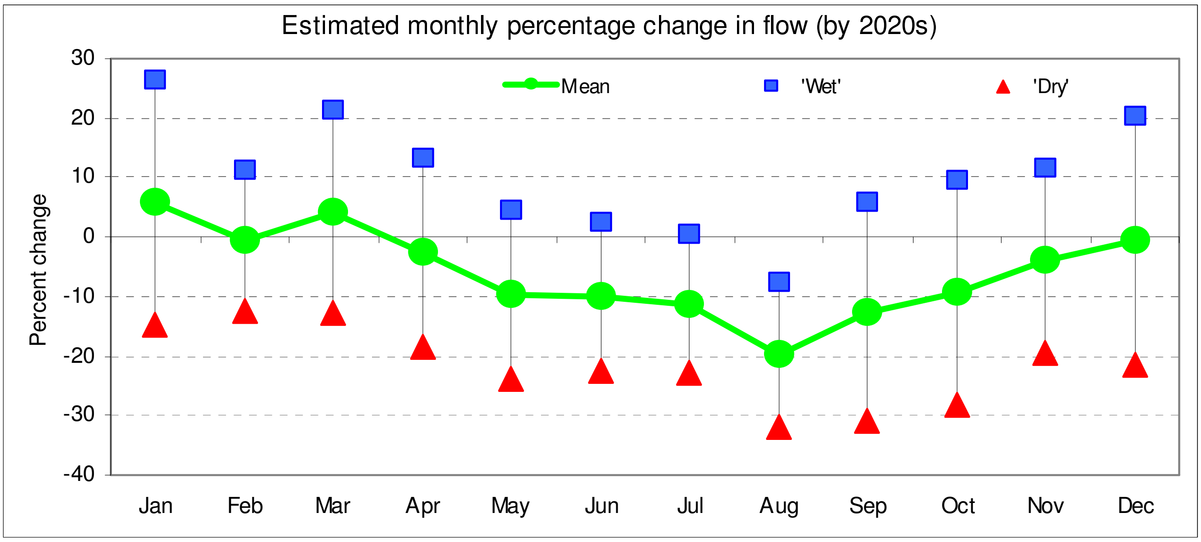
- Statutory Water Resources Management Plan Regulations 2007
- Adapting to Climate Change Statutory Guidance 2009

In addition to the ample use of regulatory guidance, we have used a range of industry standard analysis methodologies developed through UKWIR or others. There are many documents covering all aspects of asset and resources management. Some of the key documents in the context of climate change are highlighted below:

- Reassessment of Water Company Yields
- Economics of Balancing Supply and Demand
- Effects of Climate Change on River flows and Groundwater Recharge
- An Improved Methodology for Assessing Headroom
- Workbook for Estimating Greenhouse Gas Emissions
- Climate Change and the Demand for Water (DEFRA)

The UKCIP02 climate change scenarios we have considered are:

- **'Dry'** equivalent to 5 percentile or a very warm and dry prediction for future climate
- **'Average'** equivalent to the mean prediction of all of the climate change scenarios
- '**Wet'** equivalent to a 95 percentile or cooler and wetter prediction for future climate

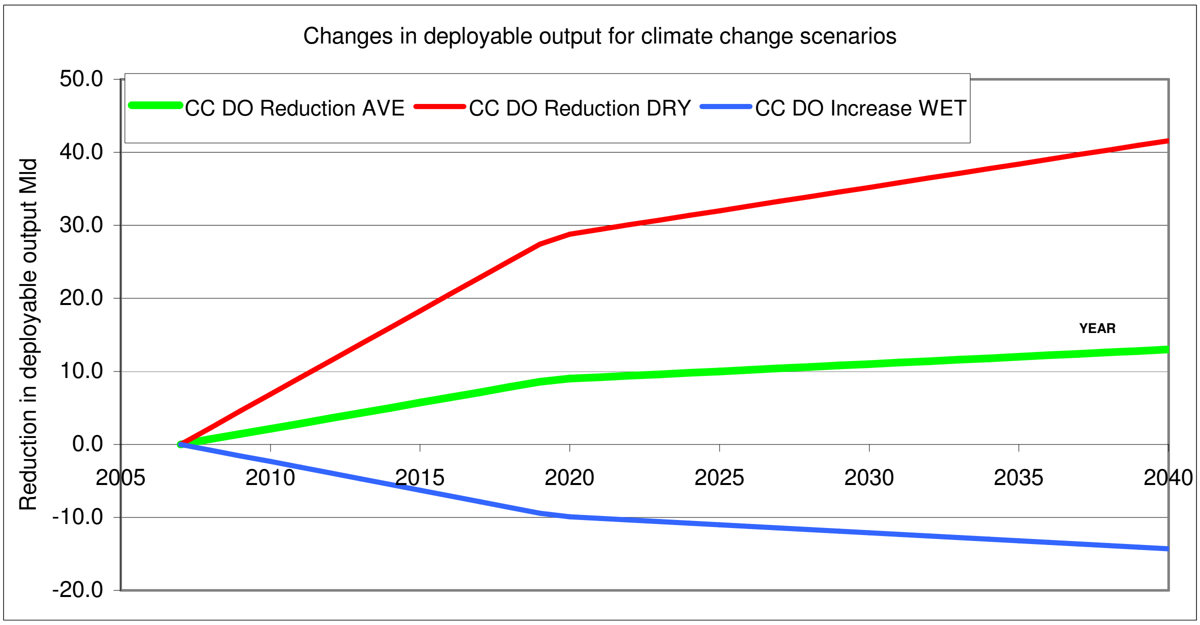


The plot above shows the 2025 monthly projected percentage reduction or increase in reservoir inflow for the dry medium and wet scenarios.

We have used these factors to perturb out long-term monthly inflow record in a model used to calculate the conjunctive use deployable output of our complete water resources system. In 2025 the projected variation of deployable output for each scenario was:

Dry	net loss of **32 Ml/d** by 2025
Medium	net loss of **10 Ml/d** by 2025
Wet	**net gain** of **11 Ml/d** by 2025

The UKWIR methodology generates a projection of deployable output reduction at 2025. We have used the methodology provided in the Environment Agency Water Resources Planning Guidelines to back-cast the annual profile of changes to 2008. The projection of annual changes in deployable output used in our WRMP assessment is shown in the plot below.



We have used the reduction in deployable output for the average impact of UKCIP02 as the central estimate of climate change impact. However, we have also used the 5 percentile and 95 percentile values for in the calculation of headroom requirements.

3.3 Impact of UKCIP09 climate projections

In 2009, new probabilistic projections of climate change were made available. Unfortunately the complexity and quantity of the data meant that existing methodologies were not suitable for analysis of the data in the same way as for UKCIP02.

We have used some of the UKCIP09 climate change data to provide a quantitative re-assessment of the yield of the company surface water reservoir system. The water available from the reservoir system has been reassessed using a draft methodology developed for UKWIR and the Environment Agency by HR Wallingford. The current draft methodology is not fully complete and is regarded as work in progress. However, using the partial methodology we have been able to produce a comparison of the Mendip yield projection from the WRMP with the UKCIP09 projection to indicate if there are any significant differences in our catchments between the two projections.

The methodology used is set out in the UKWIR report 'Assessment of the Significance to Water Resource Management Plans of the UK climate projections 2009' 09/CL/04/11. A summary of the work was carried out to establish changes to total system deployable output caused by changes in reservoir inflow is set out below:

- HR Wallingford produce 20 samples for the Severn from UKCIP09 covering data using specialised sampling technique for the medium emissions scenario.

- The Wallingford sample included rainfall variation factors and calculated potential evapotranspiration data for river basins (not provided in UKCIP09 dataset).

- A fully calibrated Hysim rainfall run off model covering our 5 Mendip catchments was produced in 2003 and updated in 2009.

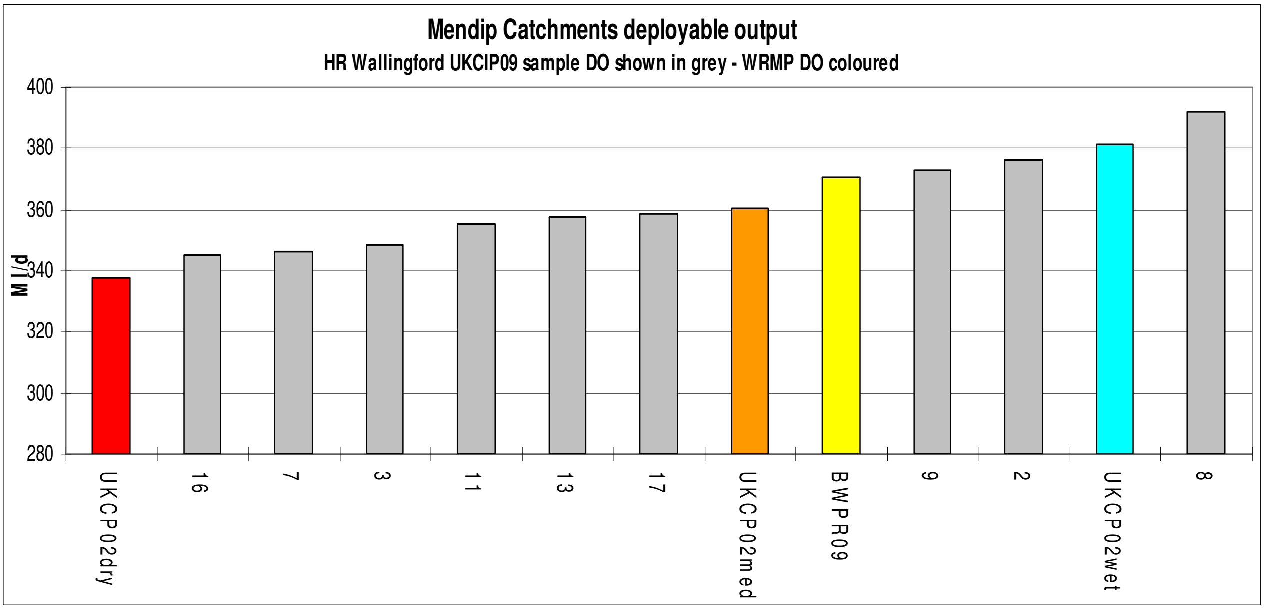
- The Hysim model is based on a 100-year historic daily data set covering some of the worst droughts in the 20th century.

- The Hysim historic data set was perturbed to give 20 different model outputs for reservoir inflows based on the HR Wallingford 20 samples of climate change impact from UKCIP09.

- The 20 inflow datasets of reservoir inflow were entered into a mass balance water resources planning model used to calculate conjunctive use deployable output allowing a value for each sample to be prepared that would be directly comparable to the UKCIP02 figure reported in the WRMP 2009.

We understand that this is an interim methodology primarily to allow a basic comparison of the two UKCIP data sets. Further research is underway funded by UKWIR to establish an industry standard methodology to calculate actual inflow reductions over time.

The comparison between the WRMP 2009 deployable output and the results from the new methodology using UKCIP09 for the mid 2020's is shown in the plot below.



In the graph, the projection of deployable output using the WRMP 2009 method are shown for the medium (orange), dry (red) and wet (blue) impacts of climate change in 2025. The present baseline system deployable output (yellow) is also shown for comparison.

The deployable output calculated using the UKCIP09 data from the HR Wallingford samples are shown in grey (only a representative extract of these outputs were plotted as some sample outputs were very similar in outturn value).

The UKWIR quick comparison shows clearly that there is very little difference between the range if climate change impacts derived from the WRMP 2009 method and the revised method using UKCIP09 outputs. We are therefore confident at this stage in continuing to use the WRMP 2009 assessment of climate change impact until a new and improved methodology is finalised for assessing the impact of UKCIP09 projections on deployable output.

3.4 Impact of climate change on demand for water

If climate change results in more frequent warmer summers and warmer winters, it is probable there will be some increase in demand for water for the following reasons:

- Increases in personal water use and consumption
- Increase in garden watering and other discretionary use
- Increase in commercial activity of service sector, food and leisure industries
- Increases in activity and type of farming and produce processing industries

To estimate these impacts, we have used research published in 2003 ‘Climate Change and the Demand for Water’ (CCDeW), Downing et al. The research contains considerable detail of all of the assumptions made regarding the likely impacts of higher temperatures on consumption. Global factors for increased demand by UK regions for the 2020s are provided for both household and non-household consumption. We not modified the assumptions within the CCDeW. Further work is underway to re-assess the effect of climate change on demand lead by UKWIR, but no results are available to date.

3.4.1 Household water demand

The regional estimate of the impact of climate change on household consumption by 2025 has been taken as the average of those predicted in the report for southern and southwest region in table 3.9 in the CCDeW report.

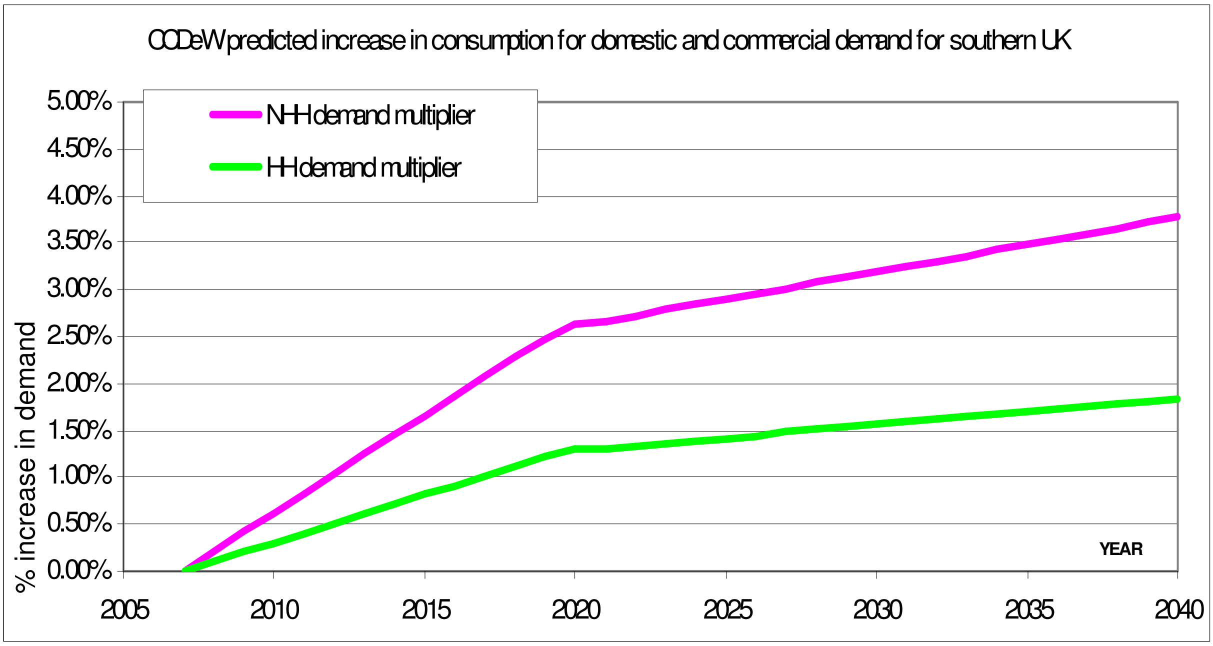
Increase in annual household demand at 2025 from climate change 1.42%

3.4.2 Non-household water demand

The regional estimate of the impact of climate change on non-household consumption by 2025 has been taken as the average of those predicted in the report for southern and southwest region for the 'beta' scenario in table 4.10 in the CCDeW report.

Increase in annual non-household demand at 2025 from climate change 2.85%

The plot below indicates the growth factors applied to the current forecasts of average consumption.



Section 4. Risk Assessment Methodology

4.1 Review of critical assets

The assets regarded as most critical to the long term operation of the business have been identified on the basis of the following parameters:

- The scale of impact on stakeholders and business if asset degraded or compromised
- The significance of the asset to the business operation
- The complexity and cost of long term or short term adaptation
- The degree to which it is possible to identify the impact of climate change
- The timescale over which the asset may be impacted or compromised

As a public water supply operation, water in rivers, reservoirs or underground aquifers available to the business under statutory licences is regarded as a critical asset. Derogation to quantity or quality to this particular class of asset would have significant implications for the business and stakeholder risks or in terms of bearing the cost of managing those risks. Our list of critical assets includes:

- The total water resources system (the quantity of water the system can produce)
- Large impounding and storage reservoir structures (overflows and failure)
- Water stored in reservoirs and aquifers or in rivers (quality and environmental)
- Large or significant individual water sources (boreholes or river intakes)
- Large or significant water treatment works (water quality and ability to treat)
- Water distribution networks and reservoirs (structural integrity and capacity issues)
- Water distribution networks and reservoirs (water quality issues)
- Pumping plant, computer networks, ICA and SCADA systems

In addition to the direct effects of climate change on particular assets, we have also considered the potential impacts on the key operational requirements:

- The supply chain and ability to provide essential treatment chemicals
- Power and telecoms suppliers
- Major third party infrastructure including flood defences
- Customer level of service expectations
- Environmental maintenance
- Staff health and welfare

4.1.1 large scale climate change adaptation risks

Critical climate change risks affecting water availability and demand for water has already been identified directly as part of our statutory functions as a water supply company and included in the latest WRMP and the FBP. These include:

- Impact on the yield of water resources
- Impact on demand for water
- Impact on greenhouse gas emissions of adaptation
- Social and economic costs of adaptation
- Impact on investment
- Network resilience

4.1.2 Asset and operational climate change risks

In addition to the macro resources risk, there are potential climate change impacts on individual assets and system operation that could range from mild inconvenience to major service failures or substantial future investment requirements. Consideration of what constituted the most critical infrastructure for the business and the estimation of the impact on climate change for that infrastructure was carried out by discussion with managers and operating staff.

4.2 Assessment methodology

To assess risks for asset classes we use a planning tool developed by consultants MWH for WaterUK, 'A Climate Change Adaptation Approach for Asset Management Planning' (2007).

This is a conventional risk analysis spreadsheet tool that covers most of the common asset classes. We have used a modified version of this tool to assess the risk to our particular circumstances that may arise from changes to parameters such as maximum summer temperatures, or maximum rise in sea level. The approach adopted considers a scenario or scenarios arising out of the basic UKCIP09 data for the southwest region, as it may affect each asset class.

For example, if the climate change data indicates that average winter temperatures and rainfall are increasing significantly, we expect an increase in frequency of increase pesticide concentrations in raw water with time (because this is occurring at present under warm and wet conditions). We manage these events by taking an affected source out of service and replacing the 'non produced' water temporarily from other sources. Depending on the asset under condition, the consequences may be minor, or substantial if an affected source required additional treatment because there was no alternative supply available.

We have developed this approach by consulting operational staff and managers to risk-assess the various impacts on critical assets classes or operations in their areas of competence. The results of this process are moderated to ensure like impacts on similar assets have consistent consequences and risk scoring.

In our risk analysis, we have adopted a scoring methodology that attaches more significant weight to issues that would take a long time to plan and resolve, or result in severe customer impacts or be very costly (the need to upgrade a treatment works would be a good example). Issues that cause a negligible or short-term loss of service that could be addressed by simple measures quickly and cheaply applied would result in a low score for overall risk. Minor plant overheating ultimately resolved by adding ventilation would be an example of a low-grade risk.

The risk for each climate change parameter/asset interaction is derived conventionally from the product of the likelihood and the impact. We have defined these components of risk as set out below:

LIKELIHOOD

- **Almost certain** Greater than 70% probability of occurrence over next 30 years
- **Most likely** A 50% to 70% probability of occurrence over next 30 years
- **Likely** A 10% to 50% probability of occurrence over next 30 years
- **Possible** A 1% to 10% probability of occurrence over next 30 years
- **Improbable** Less than a 1% probability of occurrence during the next 30 years

CONSEQUENCE

- **Very high impact** Business or customer critical negative impacts that could result in lasting business, social or economic damage if not addressed.

- **High impact** Serious negative outcomes that result in failure to deliver strategic and stakeholder objectives or result in failure to meet agreed customer and regulator levels of service. Significant financial losses and long period of business recovery.

- **Medium impact** Moderate negative outcomes from residual risk or lost opportunity that if ignored could impact stakeholder objectives or give rise to stakeholder concern. These consequences can be managed in the medium term without reduced levels of service, or regulatory impacts and with full business recovery over a short period.

- **Low impact** Minor negative outcomes that have no significant or permanent effect on stakeholder objectives or operational activity. Consequences can be adequately managed in by short term measures at minor cost to the business

- **Negligible impact** Insignificant impact on stakeholder objectives or regulatory levels of service and business costs.

These individual components are scored from 1 to 5, 5 being given for high probability of occurrence or a high impact. These scores are multiplied to produce a matrix of the overall risk perceived due to climate change for each of the critical assets or groups of assts, as set out in the table below.

		RISK				
Very High	5	5	10	15	20	25
High	4	4	8	12	16	20
Medium	3	3	6	9	12	15
Low	2	2	4	6	8	10
Very Low	1	1	2	3	4	5
impact		1	2	3	4	5
	likelihood	Improb'le	Possible	Likely	Most Likely	Almost Certain

Assets or operations that score above 15, i.e. have 'very high' or 'high' negative impacts and have a more than 50% probability of occurrence are taken forward to be included in a programme of future adaptation. However, the items that score less are not ignored or discarded. As part of our overall business risk management, the lesser risks are logged and monitored in the business risk register. If in future it was perceived that an item risk profile was changing in response to climate and this was having unforeseen or substantial impacts, the risk rating would change and the issue would then be addressed as part of the normal business planning process.

In the tables summarising the key business risks, we have highlighted the high and very high risk items in a magenta shade. In some cases we have included medium risk items where we think that these may move to a higher level of risk in future. These are highlighted with green shading.

4.3 Key Business risks – Water Resource Assets

The highest risk climate change impacts on the future availability and quality of water resources are tabulated below.

The greatest long-term risk that the company and stakeholders face in the future is a reduction in the total amount of water available from our total resources mix. This may either be due to widespread gradual reduction in source yields. In addition, if resources are not available for extended periods, the water available to maintain the supply demand balance will also be reduced. The same would be true if we were required to reduce water abstractions for regulatory or environmental reasons. Reductions in the water available would effectively mean a reduced security of supply and either increased frequency of restrictions to customer's use of water, or in the worst case a potential supply failure. All of the risks identified in the table below would ultimately result in a loss of water available if manifest to their full extent.

There are few available potential new water resources remaining in our supply area. The development of significant new water resources is costly and takes a long time due to the complex planning issues (typically many times longer than any other infrastructure such as mains or treatment works). Detecting a permanent loss in deployable output due to climate change is difficult in practice. The shortage of water available may only become apparent when an unusual event occurs, by which time it is too late to prevent the resulting negative impact upon customers.

In some instances, there is some operational evidence that negative outcomes may already be occurring. An example would be the recent increases in nitrate levels in some of our groundwater sources during wet winters. Where levels exceed the prescribed value, the source is removed from service to comply with water quality standards. So far, impacts will reach a threshold that requires action within the next 10 years . Where medium term negative impacts have been predicted, future investment has been identified in both our WRMP and FBP planning documents detailed, in the section on adaptation actions.

WATER RESOURCES Critical assets impacted	Climate change variable	Effect of variable on asset	Effect on stakeholders	Effect on organisation	Probability of outcome	Timescale for risks to materialise	Adaptation actions
Water resources yield from reservoirs	Decreasing rainfall (linked to higher temperatures)	Reduction in yield, less water available	Decreased security of supply, more frequent use restrictions	Higher costs, regulatory failure	High likelihood of occurrence,	Impacts may be occurring now, Material effects within 10–15 years	WRMP twin track demand management and new sources development
Boreholes and wells	Decreasing rainfall (linked to higher temperatures)	Reduction in yield or levels, less water available - possible failure	Loss of supply some wells are critical for local supply	Higher costs either from emergency measures or Adaptation	High likelihood of occurrence	Impacts may be occurring now, Material effects within 10–15 years	WRMP twin track SBS resilience schemes
Reservoir water storage	Intense rainfall and pluvial flooding	High volume overflows	Overflows contributing to local flooding	Regulatory pressure to maintain low levels resulting in loss of yield	If flooding frequent, Floods and Water Act would permit action	10-30 years	Would need to develop new resources
Intakes, wells aqueducts, boreholes	Intense rainfall and pluvial flooding	Rapid infiltration, contamination treatment failure quality failure	Loss of service- some wells are critical for local supply	Higher costs, reduction of water available from increased outage	Can happen now, frequency will increase as rainfall intensifies	Material effects within 10–15 years	Catchment management may need to improve treatment process
Reservoir water storage and availability	High daily temperatures or high summer temperatures	Higher water demand (PCC) and high evaporative losses	Reduced local security of supply potential local supply failure	higher costs for unusual transfers of water between resources	Quite high probability based on past trends for temperature rise	10-30 years issues can occur now in some areas but are manageable at present	WRMP twin track Strategy and SBS resilience schemes

Critical asset impacted	Climate change variable	Effect of variable on asset	Effect on stakeholders	Effect on organisation	Probability of outcome	Timescale for risks to materialise	Adaptation actions
Reservoir water storage and availability	High summer long temperatures	Rapid drawdown, algal blooms de-oxygenation of water with stagnation ecological damage (fish deaths)	Water develops taste and odour problems, loss of recreational amenity value in reservoirs	Higher treatment costs adverse regulatory impacts on SSSI quality	High likelihood of occurrence as these vents take place now and will increase in frequency	Impacts may be occurring now, Material effects within 10–15 years	Will need to monitor, may need changes in operation, treatment works or artificial aeration of reservoirs
Reservoirs, wells and boreholes	Inundation or fluvial flooding	Extreme quality impacts making sources not fit for use (nitrate or metaldehyde, coliforms, etc)	Loss of supply from affected sources until flooding subsides	Higher costs either from emergency measures or adaptation	High likelihood of occurrence but Adaptation in place or planned for some sites	Further effects within 10–15 years	WRMP twin track and SBS resilience schemes
Reservoirs, wells and boreholes	Combination effects of high temperature and low rainfall	As identified in rows above	Reduced water in environment and low river flows, WFD compliance issues	Regulatory requirements to reduce water abstraction, loss of abstraction licences	Already occurring for some parts of the UK	Within 20- 40 years	Loss of licenced abstractions would require development of replacement sources
All water resources	Increasing drought frequency, intensity or length	Security of supply failure	Increasing restrictions to customer use loss of service, loss of supply in the worst case	Regulatory failure and fines, high costs of implementing drought contingency plans	Unknown, no evidence to date UKCIP09 has no projection for return periods	Effects may take time to be observed by which time it may be too late to mitigate before stakeholders are impacted	New resources, or agreed reduced level of service or agreed water rationing by tariff

4.4 Treatment works assets and water quality

Treatment works and processes have developed to be able to deal effectively with an historic range of water quality challenges. As drinking water quality standards have changed, processes have been upgraded. Climate change now adds an additional dimension, in that the future deterioration in raw water quality needs to be addressed.

We already see an increasing trend for incidents such as high nitrate or pesticide loadings in water from changing agricultural practices. Higher temperatures can also cause issues such as formation of unacceptable levels of bromate and halogenated hydrocarbons in treated water. Many of the identified risks are adequately managed at present by increasing chemical use or changes to system operation (at increased cost).

Climate change may impact on the operation of treatment works to cause significant outage affecting water available as covered in the section above. Significant but lesser risks are due to short-term failures causing local operational problems or quality risks to customers. This category of risk is of a lower order because adaptive measures can be carried out in a much shorter time scale than required for the development of new resources. Typically we would change or add new treatment process stages as required, or put in place network resilience schemes to ensure dual supplies to maintain customer service. The issue becomes one primarily of increasing operational or capital costs

The table below sets out the primary risks to water quality and treatment works that could occur as a consequence of climate change.

WATER TREATMENT Critical asset impacted	Climate change variable	Effect of variable on asset	Effect on stakeholders	Effect on organisation	Probability of outcome	Timescale for risks to materialise	Adaptation actions
Major treatment works with ozone stages	High daily temperatures or high summer temperatures	Production of chlorinated hydrocarbons increase higher treatment cost	Water not meeting standards or interruption to supply	Regulatory failure, higher costs of operating	High likelihood of occurrence,	Impacts may be occurring now, Material effects within 10–15 years	FBP resilience schemes to supply affected area from other sources
Treatment works	Increasing winter temperatures changing crop patterns	Nitrates and pesticides that are not currently treatable	Water not meeting standards or interruption to supply	Regulatory failure, higher costs of operating	High likelihood of occurrence	Impacts may be occurring now, Material effects within 10–15 years	FBP resilience schemes to supply affected area from other sources and catchment management
Treatment works	Intense rainfall and pluvial/fluvial flooding	Outage due to plant shut down	Interruption to supply requiring delivery of alternative water supply	Regulatory failure, higher costs of operating	At risk now frequency may increase in future	20 to 40 years	FBP schemes to supply affected area from other sources and provide flood defence
Surface water treatment works	Higher temperatures	Increase in chemical use	Increased risk of poor quality water events, poor taste, and discolouration	Higher use of treatment chemicals, higher costs, regulatory failure	Can happen now, frequency will increase as rainfall intensifies	Material effects within 10–15 years	Catchment management, improved treatment process
Treatment works	Higher temperatures	Poor influent water quality giving high concentrations of iron and manganese	Complaints of poor colour and taste	Higher use of treatment chemical higher costs regulatory failure	Probable due to temperature rise, but difficult to see trend at present	10-30 years issues can occur now in some areas but are manageable at present	FBP resilience schemes Frequent failure will drive investment
Treatment works	Intense rainfall	Higher turbidity load	Complaints of poor taste and odour	Higher use of treatment chemicals higher costs regulatory failure	Probable due to rainfall intensity increase difficult to see trend at present	10-30 years issues can occur now in some areas but are manageable	FBP resilience schemes Frequent failure will drive investment

4.5 Treated water network assets and operations

The treated water network includes all pipeline, service reservoir and plant and pumping assets downstream of treatment works. We have identified possible effect of climate change on these assets. In general the scale of impacts are of a lower order than impacts on resources. While there could be short-term or intermittent service and regulatory failures, these would be addressable in a relatively short period of time.

The exception to this is the potential impact of climate change on the aging mains network. Ground movement may reduce the integrity of the mains network and differing temperature regimes may increase the rate of asset deterioration. If this is the case, it is likely that leakage may increase. In our WRMP we have set out a long term strategy to reduce the quantity of water lost from leaking mains as a means of maintaining the supply demand balance. If the rate of mains deterioration and leakage exceeds the current estimates, we are at risk of regulatory failure with respect to our leakage targets, as well compromising customer level of service with a deteriorating supply demand balance.

The table below sets out the primary risks to the treated water network and associated assets that could occur as a consequence of climate change.

WATER NETWORKS Critical asset impacted	Climate change variable	Effect of variable on asset	Effect on stakeholders	Effect on organisation	Probability of outcome	Timescale for risks to materialise	Adaptation actions
Distribution mains	Reduction in summer rainfall drying ground causes increased subsidence, heave and rapid ground movements	Stress on mains joint failures mains failures and increasing leakage	Temporary loss of supply, higher cost in long term if leakage reduction becomes more costly	Regulatory failure from not meeting leakage targets	High likelihood of occurrence	Material effects within 10–15 years, but only observable during hottest years	WRMP strategy to maintain leakage target may be achievable but at higher cost
Distribution mains and pumping plant	Reduction in summer rainfall leading to higher demand for water	Demand for water exceeds the capacity of assets in peak demand periods	Low pressures peak period supply failure	Regulatory failure from not meeting service targets increase in compensation payments	High likelihood of occurrence	Material effects within 10–15 years but only observable during hottest years	Network monitoring for regulatory targets
Distribution mains and pumping plant	High summer or daily temperatures leading to much higher demand for water	Demand for water exceeds the capacity of assets in peak demand periods	Low pressures peak period supply failure	Regulatory failure from not meeting service targets, increase in compensation payments	High likelihood of occurrence	Material effects within 10–15 years but only observable during hottest years	Network monitoring for regulatory targets
Distribution service reservoirs	High summer or daily temperatures leading to much higher demand for water	Demand for water exceeds the capacity of assets in peak demand periods	Loss of service and supply failure	Regulatory failure from not meeting service targets, increase in compensation payments	May occur in peak periods	Material effects within 10–15 years	Network monitoring for regulatory targets
Distribution mains	Higher temperatures	Increased bio film reduced chlorine residuals Increasing MDPE join failures	Risk of contamination taste and odour problems increased complaints	Regulatory failure from not meeting service targets. Increased leakage from new MDPE mains	Probable due to temperature rise, but difficult to see trend at present	Material effects within 10–15 years	Increased mains flushing may be required Network monitoring for regulatory targets

4.5.1 Company wide operations

In addition to the direct effect of climate change on company assets, we have assessed the risk to the following business operations:

- Short term environmental damage of dry periods
- Increased subsidence or damage to structures during dry periods
- Transportation difficulty during flooding events
- Loss of SCADA, ICA signals
- Climatic effects on staff in extreme weather

Most of the operations are not considered very high risk items as the consequences in terms of customer and business impacts are relatively short term or minor, or the risks have been mitigated already.

4.5.2 Third party interdependency

The day-to-day operation of the business is dependent on others to provide critical goods and services. These external operations will also be impacted by climate change (and be best placed to develop their individual strategy to address those impacts). The key organisational interdependencies we have identified are:

- Supply/availability of critical treatment chemicals during extreme weather
- Security of electricity supply to major treatment works
- Resilience of communication networks
- Resilience of third party assets (flood defences, Sharpness canal and pumps)

These risks within these interdependencies are not as well detailed or understood as our own business risks. As part of our general risk management, we have been aware of these dependencies and have already built in a degree of resilience in our operation to cope with emergency events.

<u>Power supply and distribution</u>

The smaller sources, operating depots and treatment works have automated on site generation in case a failure of the grid supply.

Of our six large critical treatment works, five have dual grid supplies. The largest site at Purton has a power requirement in excess of 1 Mw does have a dual power incomer, but both are from a single substation at Walham near Gloucester. This critical piece of power supply infrastructure was almost flooded during 2007.

<u>Critical water treatment chemicals</u>

Treatment chemicals and analytical reagents are essential to the continued operation of treatment works. Where possible we endeavour to hold suitable levels of chemical stocks on the works site. The amount that can be held on site is usually limited by the available storage facility. The resilience of the works is dependent on the maximum number of days storage of a single critical chemical. (i.e. having 30 days storage of caustic soda would be irrelevant if only 5 days supply of testing reagent was available).

We aim to hold minimum stocks of all required chemicals of at least 14 days. Stock levels are automatically and manually monitored, triggering orders from suppliers at pre determined levels. Where possible, we have set up dual contractor supplies to ensure continuity of supply should one party be unable to deliver. This arrangement has not been possible for all treatment chemicals as in some cases there is only a single supplier or distributor within the UK. We continue to work with manufacturers and distributors to improve the security of the supply chain.

Communications networks and providers
For critical and large company sites we maintain independent dual networked communication by both landline and microwave. Smaller operating sites may have a backup system via radio link, or may default to local control and in the worst instance are designed to fail-safe (essentially shut down until manually re-set). The communications hubs are designed to automatically switch in the event of failure.

In the case of a wider public telecommunications failure, the company operates with both cell-phone and landline networks. Should these two systems fail, a low band radio system is available. Although this has limited capacity, it will provide basic communications in the event of a severe emergency such as flooding that may disable part of the public network.

Third party infrastructure
We are also dependent on the following large-scale infrastructure

- The Severn Estuary flood defences maintained and operated by the Environment Agency

- The River Severn Clywedog and Shropshire groundwater transfers operated by the Environment Agency

- The Gloucester and Sharpness canal and pumping stations at Gloucester owned and operated by British Waterways

The first two are covered by planning agreements or are covered by a long term plan to ensure the current rights or protections are maintained. We expect to work with the Environment Agency in future to ensure that these plans remain fit for purpose in the face of any future climate change risks.

We have planning and level of service agreements with British Waterways to ensure that the risks of operation of the canal are minimised with respect to water abstraction. This agreement includes emergency repair and pumping arrangements to the canal and associated infrastructure in the case of:

- A breach or collapse of the canal
- Failure of major locks or pumps
- Inadequate water quality or pollution of the canal
- Inundation of flood or salt water of the canal
- Consultation regarding canal maintenance requirements

We will continue to work with British Waterways to ensure that these agreements remain sufficiently robust to cope with the effects of future climate change on these assets.

Section 5. Climate Change Adaptation Actions

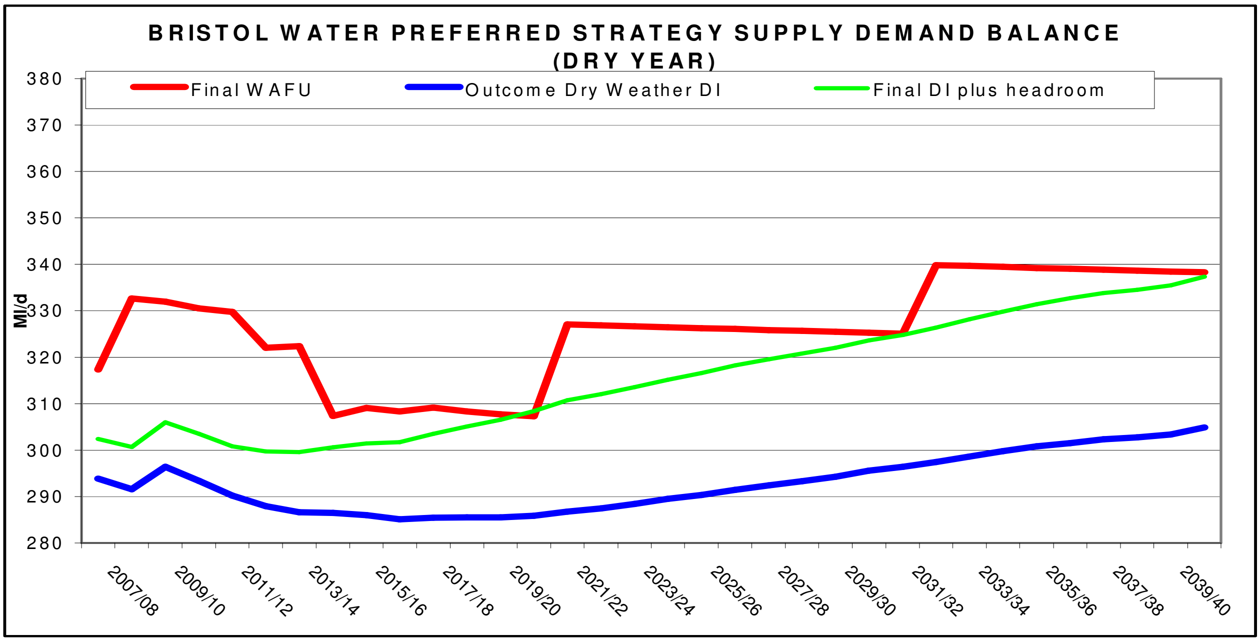
5.1 Water Resources – maintaining the supply demand balance

In our WRMP, we set out how we intended to maintain the supply demand balance so that customer security of supply and levels of service would not be reduced over the next 25 years. Over the planning period, the impact of climate change was only one of many risks addressed and factored into to the basket of options required to deliver the WRMP. The more significant risks within the WRMP are listed below in decreasing order of magnitude:

- Regulatory uncertainty
- Uncertainty in population and housing forecasts
- Uncertainty in projections of future household consumption
- Uncertainty in economic growth and business use of water
- Uncertainty in reliability of plant (outage due various factors)
- Uncertainty associated with ageing and underinvested infrastructure
- Uncertainty in projections of housing growth
- Central estimate of reduction in deployable output and consumption due to climate change

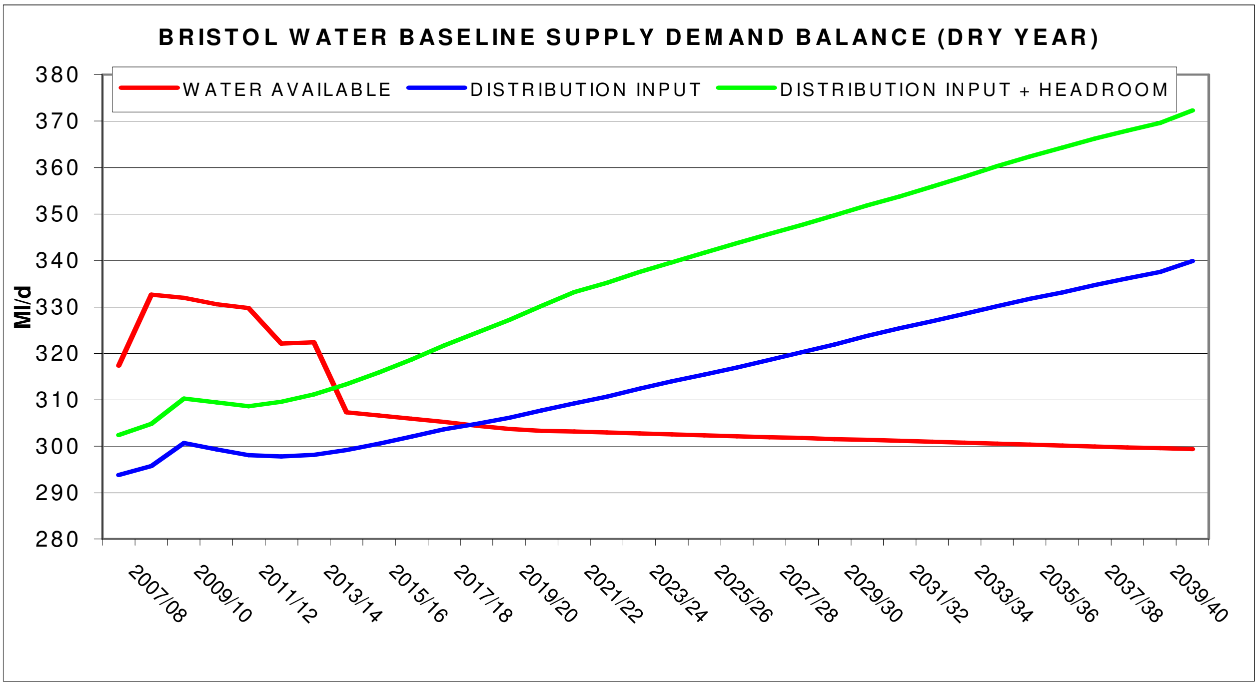
There was a wide range between the 95 and 5 percentile climate change impacts on water available. By 2040, the projected effects varied from a reduction of 40 Ml/d on water available from 370 Ml/d to 330 Ml/d, to an increase in deployable output up to 395 Ml/d. In the plan, a central estimate of a 12 Ml/d reduction in deployable output was used. The significant headroom component was partly due to the wide variation in the UKCIP02 projections. Headroom is a quantified estimate of the planning margin required to absorb residual future risks to customers that arise from the uncertainties in long range planning.

The graph below shows the volume of water available allowing for the provision of non-potable supplies in red. This is plotted against the projection of water demand and water demand with the headroom allowance. The plot represents the supply demand balance if our WRMP was fully implemented.



The plot shows that by 2020 and again by 2031, significant water resources developments are implemented (or at least be at an advanced stage of planning). This is the conventional way of indicating the balance between supply and demand.

Our least-cost planning scenario should be compared to the baseline 'do nothing' scenario plotted below. Te baseline position shows that if no action were taken, customers would face a deteriorating security of supply with an increasing risk of restrictions to supply from 2013 onward and then would be at substantial risk of supply failures from 2017 onwards.



The planning method does not expose the cost of adapting to a single issue risk such as climate change as a stand-alone item. The industry standard cost optimisation method is based a holistic planning approach where a 'basket of risks' is mitigated by a 'basket of options' chosen to deliver benefits at the lowest overall economic and social costs over time.

5.2 Adaptation actions to minimise risks to security of supply

The activities proposed are chosen to comply with the 'twin track' approach required by the Environment Agency. This means some actions are targeted at reducing demand for water or increasing efficiency. These are implemented across the entire period. Other actions to develop existing or new resources have a specific date for implementation.

The least cost actions have been selected from a long list of all technically feasible options set out below. When costing the schemes, the construction, social and environmental costs have been considered, including carbon costs and social benefits. A detailed methodology is provided in the WRMP and the Strategic Environmental Assessment of the plan. The table below compares the social cost of each scheme and the expected benefits in terms of the water made available on full implementation of the scheme. Schemes that have the lowest incremental costs are selected for inclusion in our long term WRMP.

OPTION DESCRIPTION [Insert / delete non-numbered lines to suit]	OPTION REFERENCE No.	WAFU ON FULL IMPLEMENTATION (Ml/d)	AIC (p/M3)	AISC (p/M3)
Customer Side Management, Specify Below....				
Business Customer Audits	D005	1.5	20.0	19.1
Change of occupier large garden	D004	1.2	70.2	55.9
Non-Household metering	D010	0.3	88.1	73.3
Intelligent Metering Radio Networks	D0020	0.1	89.9	134.0
Cistern displacement device distribution	D016	0.2	137.4	150.2
Compulsory	D011	1.1	178.8	156.1
Change of occupier	D003	1.2	294.4	238.0
Retro-fit WCs with dual/variable flush devices	D006	0.3	1048.5	1058.2
Distribution Side Management, Specify Below....				
Permanent WWMD logging	L006	0.5	-2.0	3.3
Pressure Scheme summary	L007	3.9	-0.3	-1.1
Leak noise loggers ALC freq/year > 5 per wwwmd	L000	0.2	0.6	1.4
Doubling ALC expenditure	L005	4.7	33.5	33.9
Subsidised Service Pipe Replacement	L004	0.33	50.0	48.8
Extension of Free Private Leak to all households	L008	0.5	61.8	61.3
Lead CP Replacement	L003	0.53	65.5	64.2
Zonal Replacement	L002	0.26	93.4	94.6
Mains Replacement with Services	L001a	0.10	187.2	193.8
Mains Replacement	L001	0.01	1134.1	1186.2
Production Side Management, Specify Below....				
Stowey WTW Wastewater Recovery	S012	2	5.2	9.1
Resource Management, Specify Below....				
Honeyhurst Well	S020	2.4	26.1	26.5
Minor Sources	S006	4.7	53.9	54.4
Forum Spring	S028	1	58.1	58.6
Gurney Slade Well	S022	1.5	58.1	58.6
Cheddar New Reservoir	S001	20	59.4	59.1
Severn Springs	S002	15	61.1	61.8
Southern Sources Upgrade	S017	6.7	62.3	63.3
City Docks/Barrow Transfer	S012	30	64.4	66.6
Chew Valley pumped storage	S015	30	74.8	78.2
Charterhouse Spring	S026	0.8	80.1	80.6
Holes Ash Spring	S024	0.8	84.5	84.9
Desalination	S008	30	91.2	96.0
Effluent Reuse Commercial	S007	20	94.1	97.4
Effluent Reuse	S016	20	117.8	122.6
Purton Bankside Reservoir	S013	25	125.8	131.4
Consolidated Mendip Sources	S004	6.7	208.1	217.5

The list of least cost adaptation actions selected to maintain customer security of supply is tabulated below and can be referenced to the full scheme descriptions in our WRMP. None of the individual schemes are driven entirely by climate change. However, individual schemes within the total basket provide resilience to general climate change impacts. For example:

- Redeveloping old water sources helps reduce long distance pumping and carbon cost
- A new reservoir captures excess winter river flows and may help reduce flooding risk
- Reservoirs offer resilience to climate change impact of dry summers and wet winters
- Water efficiency measures helps offset the impact of rising demand from warmer summers

REF	OPTION NAME	DATES
L005	Active Leakage Control	2010 to 2035
L007	System pressure reduction	2010 to 2015
L000	ALC leak noise logging	2010 to 2035
L006	Permanent district logging	2010 to 2035
L008	Extending free supply pipe repair scheme	2015 to 2035
L004	Subsidised supply pipe replacement	2015 to 2035
L002	Zonal based replacement of infrastructure	2010 to 2035
D005	Business customer audits	2010 to 2035
D004	Change of occupier metering (large gardens)	2010 to 2020
D011	Compulsory metering with infrastructure maintenance	2020 to 2035
D010	Non household metering	2010 to 2020
D020	Smart metering trials with radio networks	2010 to 2015
S020	Honeyhurst well return to service	2012 to 2014
S022	Gurney Slade well return to service	2016 to 2018
S001	Cheddar reservoir extension	2020 to 2025
S002	Severn Springs development (or other large resource scheme)	2030 to 2035

The implementation of this basket of options results in the following total cost over the planning period:

- NPV of total solution £168 million
- NPV of carbon costs £ 1 million
- NPV of social costs £-85 million

The reduction in social costs is due to the positive social benefits associated with the Cheddar reservoir extension and leakage reduction.

Total NPV of strategy cost £83 million over 25 years

The shorter term costs over 5 to 10 year of these and other schemes are reported in detail in our Final Business Plan (FBP) submitted to Ofwat as part of the Periodic Review process. Some planned activities due to start in the period 2010 to 2015 were not supported by the regulator (a new resource at Honeyhurst Well and key network resilience improvements). These options will be reconsidered in the WRMP and business plan at the next periodic review (AMP6).

5.3 Adaptation actions minimising risks to water resource assets

Raw water storage reservoirs and aqueducts are a key component of our system and are subject to impacts of climate change. Understanding quite how climate change may impact these structures in detail is problematic given the rather general nature of the UKCIP09 projections. These sites are subject to an intensive ongoing programme of monitoring to meet statutory requirements as detailed in section 2.

Our overall planning approach is to maintain and improve the resilience of these structures. While these improvements may not be driven entirely by the impacts of climate change, they are a significant part of the rationale behind ongoing improvement of system resilience.

For the larger reservoirs, there is an ongoing programme of surveys to monitor:

- Embankment stability via crest and marker post surveys
- Embankment water levels via permanently installed piezometers
- Toe drain flows which are cross referenced to rainfall

Other work required is summarised in the following table.

Reservoir	Details	Benefit
Barrow Nos 1 & 2	Investigate leak identified on common embankment between reservoirs. May result in the need for remedial work in AMP6.	To improve the structure and ensure it is in a safe condition for future operation.
Barrow Nos 1 & 2	Replace interconnecting valve with a weir.	Insufficient spillway capacity.
Barrow Nos 1, 2 & 3	Remedial work to wave wall and stone pitching.	Assist with controlling leakage and to maintain the structure in a safe condition.
Barrow No 3	Remedial work to retaining wall adjacent to A38 to deal with instability.	To improve the structure and ensure it is in a safe condition for future operation.
Barrow Compensation	Stabilisation of the masonry culvert and 7m high A38 retaining wall.	To improve the structure and ensure it is in a safe condition for future operation.
Barrow Compensation	Extension of downstream interceptor drainage system to divert groundwater away from the reservoir toe to allow free drainage.	To improve the structure and ensure it is in a safe condition for future operation..
Blagdon	Grouting around the overflow weir structure to fill voids and eliminate leakage paths.	To improve the structure and ensure it is in a safe condition for future operation.
Cheddar	Repairs and replacement of stone pitching. Raising the wave wall to a common level around the whole circumference associated with prevailing wind direction.	To improve the structure and ensure it is in a safe condition for future operation.
Chew Valley	Construct a separate valve and pipe system to discharge into the overflow channel to overcome restrictions in the existing emergency drawdown system.	To improve the structure and ensure it is in a safe condition for future operation. and to allow it to operate safely under extreme conditions.
Chew Valley	Programme of maintenance on the 3 embankments on this reservoir including vegetation clearance and repairs to rubble protection, pitching, crest and drainage.	To improve the structure and ensure it is in a safe condition for future operation.
Litton Lower	Investigation and remedial works to overflow weir and channel to deal with movement of this structure.	To maintain the structure in a safe condition.
Litton Lower & Upper	Installation of air jetting facility on the upstream scour pipe screens to remove debris and weed.	To improve the structure and ensure it is in a safe condition for future operation. and ensure sufficient flow capacity.
Litton Lower & Upper	Carry out repairs to the overflow structure and wave wall capping.	To improve the structure and ensure it is in a safe condition for future operation.
General	Preparation of operating manuals and emergency plans to include dam break.	Compliance with requirements.
General	On-going programme of maintenance work including silt removal.	To maintain operating capability of reservoirs and to improve the structure and ensure it is in a safe condition for future operation.

Forecast expenditure on raw water reservoirs is set out in the table below for the period to 2020:

£m 2007/08 Prices	AMP4	AMP5	AMP6
Capital Expenditure	£3.5m	£5.5m	£6.3m

We would expect a similar ongoing expenditure for monitoring and maintenance of these large structures well into the future. We estimate that the direct impact of improvements to reservoirs for climate change resilience is approximately 30% of the quinquennial expenditure, or approximately £1.5 million in each AMP period. Such funding in future would allow the improvement of aeration and de-stratification systems in reservoir in response to climate change driven water quality deterioration or algal blooms, for example.

We have investigated the discharge and overflow capacity in terms of the probable maximum flood risk (PMF) of all category 'A' reservoirs where failure could result in loss of life. This study confirmed that these structures have an acceptable or low probability of failure at a 0.5 PMF or greater (0.5 PMF estimated to have a 1 in 10,000 year return period). Such long return period are outside the present scope and timing of climate change impacts. The programme of monitoring and continual improvement will be the method of adaptation to climate change.

5.4 Adaptation actions minimising risks to water treatment assets

The climate change impacts on water treatment works arise from the following:

- Higher temperatures/runoff causing changes to water quality
- Increasing intensity of rainfall causing flooding

The cost of schemes to mitigate changing water quality

	Benefits included in Assessment	**Capital costs (£m)**	**Operating costs (£m)**
Nitrate reduction - Egford	Benefits based on avoiding loss of yield during periods of high nitrate. Lost yield avoided 1.15Ml/d	4.7	0.04
Metaldehyde reduction by implementation of catchment management	Benefits based on probability of avoiding need for more complex treatment £0.473m pa. Value of minimum delay in implementation of expensive treatment of five years £11.09m.	0.5	0.1
Trihalomethane reduction at Purton using surface aeration	Benefits based on value of reducing risk of ventricular septal defects in newborn babies £0.32m pa.	0.7	0.3

5.4.1 Adaptation for water quality issues

Changes in water quality can have a significant effect on the performance of treatment works. We have observed trends in deterioration of raw water quality arising from climate change effects to date.

The highest risks to effective operation of treatment works arise from:

- Nitrate
- Metaldehyde
- Trihalomethane formation
- Low oxygen levels
- Turbidity

These impacts may be due directly to the climatic effects, such as increasing algal blooms in reservoirs due to higher temperatures. Other effects are secondary and caused by changes in agricultural land use causing higher residual levels of agrochemicals in surface and groundwater.

We expect these trends to continue as a consequence of the projected temperature rise and increase in the intensity of rainfall events. Where the concentration of a particular pollutant may exceed the prescribed value, the usual mitigating action is to take the affected treatment works out of service for the period of the pollution. This may be possible for smaller and less critical treatment works, but increasing or lengthy shut downs would have the effect of increasing the source outage, thereby reducing the system yield over time.

The mitigating action in this case would be to monitor the changes to the outage volumes and impact on security of supply until a business case can be made for capital investment to redress the balance by the most appropriate method.

Shutting down a critical or large treatment works for more than a few hours causes problems with quality deterioration within components of the treatment works. Other solutions would be required that enhance the ability of the network to move water from other parts of the system.

Increasing nitrate levels

The nitrate standard of 50 mg/l has been exceeded with increasing frequency at the following critical sources:

- Frome groundwater (Egford Wells)
- Sharpness supply (Purton and Littleton treatment works)

To treat high nitrates in the water from Egford Wells at Frome, a blending solution is proposed. This will include a 7 ML reservoir, low lift pumping station, actuated valves and interconnecting pipework to allow mixing with water from sources that have lower levels of nitrate.

There is also an associated proposal for a resilience scheme that will enable water to be transferred to the zone from other parts of the network via a new transmission main. This would allow the source to be shut down, or extend the life of the blending scheme by bringing in a greater volume of water with low nitrate concentrations.

High nitrate concentrations at the Sharpness source are managed by taking Littleton treatment works out of service and blending the canal water with stored raw water at Purton. We also have an agreement with British Waterways to ‘flush’ the canal by high rate pumping at Gloucester docks. This action would rapidly move the body of nitrate contaminated water past the canal intake to Puton and Littleton treatment works.

This solution only works for short-lived events of a few days. We will continue to monitor the frequency and nature of these events. If we believe there is a material increase in risk of supplying customers with water that does not comply with drinking water standards, we would propose alternative measures in future business reviews.

The most sustainable solution must be to stop agricultural nutrients getting into rivers and watercourses in the first place. This could be achieved through management and control of the product in the catchment rather by trying to remove it using extra energy and chemicals adding to the carbon footprint and climate change impacts.

We have implemented a catchment monitoring programme in partnership with the Environment Agency and the Farming and Wildlife Advisory Group (FWAG) to promote the careful management and timing of fertiliser or slurry use close to water courses or in sensitive groundwater catchments. If effective, such an approach could delay, or prevent the need for expensive modifications to existing treatment plants.

Increasing metaldehyde

Metaldehyde is primarily used to control slugs and snails on arable crops of potatoes and oil seed rape with the majority being applied during the period September to November. The area used to grow potatoes and oil seed rape within the affected raw water catchments has doubled in the last five years. This trend appears to be continuing as the pressure to intensify agricultural land use. The two sources most affected at present are:

- Sharpness supply (Purton and Littleton treatment works)
- Blagdon reservoir (Banwell treatment works)

The current treatment processes at Banwell and Purton Treatment Works are not sufficient to adequately remove increased levels of metaldehyde from the raw water. At present there appears to be no simple or economic treatment processes to remove metaldehayde.

As with the nitrate issue, the company will promote a catchment management approach and strongly supports a change in the licensing of the product with a view to restrict its use close to surface waters.

Trihalomethane formation

This occurs frequently at Purton particularly when water temperatures increase. The usual adaptation is to decrease the pH of the process stream before ozone is added to the water. This in turn requires additional use of chemical to correct the pH later in the process and adds to the carbon footprint and climate change impacts.

A proposal to install surface water aeration on the raw water reservoir at the treatment works may act to reduce the loading of trihalomethane in water entering the treatment works. We will monitor how effective this approach is in future.

Low oxygen levels

During periods of high temperatures, algal blooms on our large water reservoirs can result in water with low oxygen saturation. At some treatment works, this can result in manganese and iron entering solution causing discoloured water.

At present, we use aerators to prevent stratification and stagnation in the reservoirs. This together with the facility to draw water from different levels in the reservoirs helps to control the problem. If temperatures increase as predicted, the existing equipment may not be sufficient to prevent frequent occurrences of discoloured water.

We monitor the frequency of these events and will seek a permanent solution if the risks of supplying customers with discoloured water show a material increase.

Turbidity

A number of shallow groundwater sources exhibit a rapid rise in turbidity following heavy rain. As these plants are all equipped with nano-filtration membrane plants, there is little risk to customers of receiving poor quality water. Under conditions of increasing turbidity, the flow through the plant reduces and eventually the plant shuts down.

In all situations, there is sufficient network resilience in place to ensure continuity of supply, so the issue is one of increasing plant outage causing a reduction in deployable output. Our approach will be to monitor the level of outage. If total outage begins to exceed the value projected in our WRMP, we would consider additional actions.

In most cases this would mean increasing the membrane capacity. This may happen through the natural cycle of replacement, as technological improvement is resulting in membranes that can handle higher flows without blinding.

5.4.2 Adaptation for increasing flood risk

The findings from our flood risk survey indicated two sites are at risk of flooding and would present a high risk to customers and the business if impacted by the most severe events. The analysis showed that both sites have a significant and present risk of flooding (i.e. greater than 75% annual probability of flooding). These critical sites are:

- Purton treatment works and pumping station (supplies a population of 200,000 in Bristol)
- Cooks Corner network pumping station (supplies a population of 31,000 at Glastonbury)

The table below sets out the benefits of the two flood resilience schemes. Cooks Corner is primarily a distribution resilience scheme, but has been included in this section. The adaptation actions will be completed by 2015.

	Benefits included in Assessment	**Capital costs (£m)**	**Operating costs (£m)**
Purton treatment works flood protection bund	Benefits based on reduction to zero of 75% annualised risk of loss of supply to a population of over 200,000 for period of weeks at 1in 1000 year flood	0.4	0
Cooks Corner pumping station flood protection bund	Benefits based on reduction to zero of 75% annualised risk of loss of supply to a population of over 30,000 for period of days at 1in 100 year flood with further resilience scheme in future	0.2	0

For each location, the engineering solution is construction of a bund to protect the critical components of the site operation. The level of protection chosen varied at each site, as the consequences of failure have differing order of magnitude.

Purton treatment works and the Sharpness Canal

If the Purton treatment works was unable to operate for a number of days due to flooding, a population of up to 200,000 within Bristol could lose their water supply. This would be an incident similar in customer impact to, but on a larger scale than was caused by the failure of Severn Trent's Myth treatment works in 2007.

The design of the bund to protect the treatment works was chosen to provide resilience to a 1 in 1,000 year flood at the projected sea level expected in 2035.

The bund will protect the treatment works, but not the Sharpness Canal that brings water from the Severn to the works. From our flood risk analysis the residual flooding risk to this structure is 1 in 100, but this decreases to 1in 50 and as lo as 1 in 20 for some areas by 2030 with the current sea defences.

Extreme fluvial and coastal flooding will cause inundation of the canal with polluted or saline water. This could mean that water supply to two major treatment works is not available for up to three weeks while the flood subsides and the canal is flushed with clean water.

An event of this magnitude would result in a loss of supply to a population of over 200,000 in the north and east of Bristol. A loss of supply on this scale for such a large population would not be manageable by the normal means of distributing bottled water or using temporary bowsers.

We propose to minimise this risk by increasing network resilience. This would allow large transfers of treated water from our southern sources and treatment works into the northern supply area. The adaptation proposals have a dual benefit, in that they also provide improved security for southern sources. These network resilience schemes are detailed in section 5.5 below.

Cooks Corner pumping station

If the Cooks Corner pumping station was unable to operate due to flooding, the command reservoir for Glastonbury and Street would empty in a few hours resulting in a supply failure to the affected area. Because of the nature of the site it would have been impractical to provide the same degree of protection as for Purton (a 4m high bund and new 6m piled foundations would be required).

This approach would provide protection for 1 in 100 year floods. In order to mitigate the residual risks of increasing rainfall intensity, a network resilience scheme is also proposed for construction between 2015 and 2020. This will provide a dual supply for customers, improving security in the event of a pumping station failure. This scheme is covered in the section on network adaptation.

5.5 Adaptation minimising risk to water networks

A high degree of resilience is already built into water supply and distribution networks. This level of reliability has served the company well in the past. More recently, there has been a step change in stakeholder expectations and a decreasing tolerance of system failures that result in loss of service. Customers and regulators expect that levels of service are maintained or enhanced for the following:

- Secure supply without restrictions to customer use
- Provision of water with near 100% water quality compliance
- No interruption to water supply
- Adequate system pressures
- Lower levels of leakage
- Reduced environmental impacts

As part of our business planning we have addressed these issues in the context of supply and distribution networks, taking into account increasing vulnerabilities due to a changing climate. As detailed below, the climate change effects for which increased network resilience would provide a solution include:

- Reductions in raw water quality causing loss of supply from treatment works outage
- An extreme event resulting in lengthy outage of a source or treatment works
- Increasing rate of mains failure from ground movement in very dry and very wet periods
- Increasing peak demands for water exceeding network or storage capacity

5.5.1 Increasing resilience using mains networks

The forward looking strategy is to improve the level of mains resilience so that no areas with a population of over 25,000 will be dependent upon a single water treatment asset. Critical treatment and network assets vulnerable both at present and to future climate change impacts are identified in the table below:

Site	Likelihood of failure	Risk assessment	Priority
Oldford TW	Very High	Very High	Very High
Tetbury TW	High	Medium	High
Banwell TW	Medium	Very High	High
Cheddar TW	Medium	Very High	High
Cooks Corner PS	Medium	High	Medium
Various Mains	Medium	Medium	Medium

Network mains were assessed as medium risk as in most cases failure of a main repair can be carried out in a short period of time and the likelihood of a long outage is low when compared to a failure at a treatment works or pumping station.

Five network resilience schemes were identified that would reduce future risks to stakeholders from the impact of climate change at the critical sites. The cost benefit and proposed timing of scheme expenditure is detailed in the table below:

Scheme	Customers Benefiting	Timing	By 2015 £m	By 2020 £m	NPV cost £m	NPV Benefit £m
Oldford Resilience Scheme	41,000	2013-2015	14.3		12.5	128.1
Tetbury Resilience Scheme	10,000	2013-2015	2.9		2.9	21.4
Southern Resilience Scheme	204,000	2014-2017	8.3	21.2	23.1	264.8
Glastonbury/Street Scheme	40,000	2015-2018		25.0		
Mains schemes	Various	2017-2020		13.0		
Total			**25.5**	**59.2**		

The methodology used to establish the risk based costs and monetised benefits are detailed in our FBP submission to Ofwat in 2009.

5.5.2 Increasing resilience by improving service reservoir storage

Water held in reservoirs should provide the essential operational capacity to be able to maintain 12 hours unsupported demand followed by a further 12 hours zone demand (after including any supply input from other areas where available). This approach ensures there is zonal resilience to cope with failure of transmission mains and pumping stations. Many of our zones are relatively secure up to 2035 when assessed by this method. We have identified two critical sites that do not meet these standards.

We plan to increase capacity at the following reservoirs where there are current shortfalls in capacity, but sized to meet the anticipated shortfall over the full WRP period.

Area	reservoir	2035 increase in size	Reduced Interruptns p.a.	Cost 2020 £m	NPV cost £m	NPV benefit £m
Burnham	Brent Knoll	4.5Ml	794	2.9	2.8	6.1
South Bristol	Withywood	1.7Ml	534	1.5	1.4	3.9

The benefits of the extra storage are based upon a model calculating the number of interruptions that will be avoided due to the increased storage capacity.

Section 6. Uncertainties and assumptions

We have reviewed the climate change forecasts and attempted to project those changes as impacts on our system. Inevitably this is a subjective process in most cases. Where there is an objective methodology, the uncertainty of the underlying UKCIP09 projections makes it difficult to set up a meaningful central estimate for clearly defined and costed schemes. The alternative approach is to use qualitative assessment of broad scenarios to maximise flexibility of the planning solutions. This approach lacks the apparent precision of quantitative methods, but is appropriate where the range uncertainties are greater than measurable data.

The UKCP09 projections of climate change in our area in terms of temperature and rainfall appear relatively modest in effect up to 2040. For most parameters, the future change is no greater at the fifty percentile than the observed changes over the past 50 years. During that period, there has been no significant change or failure of our systems or operation that can be attributed to the measured rate of climate change alone.

The uncertainties within the adaptation planning process fall into the following categories:

- Uncertainty and missing information
- Lack of baseline data on climate change impact to date
- Uncertainty in analysis methodologies
- What adaptation strategies interdependent organisations will follow

6.1 Uncertainty and missing information

UKCIP09 provides a great deal of data and some helpful projections of average temperature and rainfall changes. However, this is not sufficient to construct a fully robust planning model.

UKCIP09 has significant data gaps in areas that would assist a better understanding of events with long return periods as set out below.

- **Droughts** – need probable changes in drought return periods, intensity or length
- **Wind** – useful in assessing potential evaporative losses
- **Evapotranspiration** – No UKCIP09 forecast, but do have external projections
- **Storm frequency** – lighting strike impacts on communications and ICA equipment
- **Storm frequency** – flooding return periods

The range of uncertainty within a single emissions scenario remains very large. This means that costed adaptation scenarios may be quite unrealistic even if all other uncertainties were negligible and could result in design or implementation of disproportionate solutions.

We have made the following assumptions within the context of Climate change projections:

- The UKCIP09 data for the medium emissions scenario represents an accurate projection of future climate change.

- That the central estimate fifty-percentile outturn represents the most likely impact.

- The future will be on a ‘business as usual’ basis without step changes in political or economic conditions, customer expectations, technology, or industry standards.

6.2 Baseline data for climate change impacts

We already have evidence for changing climate in terms of rainfall and temperature. Even when changes in meteorological parameters to date are understood, the impacts to date on the business remain difficult to quantify because at present the trends do not appear to stand out above the general variability.

In our area, average summer temperatures have increased by 3°C over the past 50 years. Both past temperature and rainfall have changed broadly at the same rate as the UKCIP09 fifty- percentile projection over the next 50 years.

Despite this period of measurable change, we are unable to correlate or link to climate change parameters the performance aspects of the business that we think may be most impacted in future. These are:

- Frequency of poor quality water events per unit trend of quantity or intensity of rainfall
- Frequency of customer water restriction per unit trend of rainfall quantity or temperature
- Return periods for extreme events per unit trend of rainfall quantity or temperature
- Frequency of mains network failure per unit trend of rainfall quantity or temperature

Without a quantitative baseline, many of the impacts of climate change we anticipate are based on the assumption that currently observed effects such as increased pesticide use in warm winters, are due to climate change. In reality there are likely to be many other factors associated with increased pesticide use.

At the current state of knowledge we are unable to deconstruct climate change as a key driver for business impacts from all the other potential drivers that could be more significant.

There have been many incremental changes to the performance and operation of our systems over time. The extent to which these may have been driven by climate change is not quantified. For example, the enhancements to treatment works over the past ten years may have been a response to cope with gradually deteriorating water quality due to climate change (albeit unwittingly). However, the actual driver for improvements was regulatory tightening of drinking water standards and monitoring.

6.3 Uncertainty in analysis methodology

The most unpredictable impact of climate change is the effect on the yield of water resources and return period of critical resources droughts. We use a standard methodology to assess these changes.

One key assumption when applying the effects of climate change to hydrological models is that future patterns of runoff and stream flow will be similar to the past and only the magnitude will vary. This is a pragmatic approach but may be wholly unjustified if completely different weather patterns emerge.

We have used this pragmatic approach to generate a statistically valid set of twenty stream and catchment inflow sequences representing the full range of climate change effects. The range of effect on deployable output is considerable, from –40 Ml/d to + 18 Ml/d. If any point in that range is equally likely, detailed forms of analysis provide limited benefits as they are outweighed by the scale of uncertainty. Other uncertainties include

- Validity of the range of UKCIP09 projections
- Suitability of the current data intense UKWIR methodology to project river flow
- Use of historic inflow sequences that may not be valid in future
- Use of CCDEW model for climate change impacted water demand may not be valid
- Lack of any means of generating impacted return periods for extreme events
- Poor understanding of thresholds or timings for action
- Lack of information regarding environmental impacts

Consideration of climate change impacts over the next 30 to 50 years needs to take into account the magnitude of those risks in relation to the many other risks that can affect the business.

The impact of climate change is only one of many risks we manage and needs to be put into its correct context. There is inherent resilience in water supply systems and the long term planning process maintains this resilience over time. To ensure a proportional response to climate change impacts we need to better understand the following:

- How small (or large) the climate change risk to customers actually is compared to other potential impacts

- How to prove adaptive actions are required only or partially by climate change

- To what extent identifying a future risk should drive a spending requirement

- At what point implementation of climate change adaptation action is required, bearing in mind the cost implication for customers of premature adaptation

- If the natural cycle of review and investment within the water industry over time is sufficient to ensure adaptation takes place organically and without requiring a separate programme

If the predictions of climate change impact are correct, it is probable that in time, the UK could have a climate broadly similar to that of the south west of France today. The infrastructure required that provides water and other critical services in that part of France appears very similar to that used in the UK and apparently functions without problem.

This fact suggests that adaptation plans for climate change need to be proportional and adaptation activity should be reactive rather than pre-emptive due to the slow pace of change. We recognise that where adaptation activity requires very long planning or construction lead times, some pre-emptive activity may be required. However this should be balanced so as to minimise investment that in time turn out not to have been required.

Section 7. Barriers to Implementation

A successful adaptation response to climate change needs to be proportional to the certainty of actual impact upon individuals and businesses, delivered at the appropriate time, and at a cost and in a manner that is acceptable to society. This generates competing priorities within society that can delay or prevent an appropriate adaptation response.

Unresolved critical interdependencies could negate the adaptive actions of businesses. For example, large energy users are reliant on the generating and transmission companies are also managing the climate change risks to their business to ensure security and resilience.

7.1 Behavioural response

There is a mixed public reaction to the facts of climate change and the uncertainty in outcomes that result. The following attitudes among individual may affect complex decisions:

- The level of uncertainty is too great to warrant any change
- Unwillingness or inability to pay more for efficiency measures or adaptation
- Perception that there will be inconvenience associated with adaptation
- ‘I pay for the water so I will use as much or as little as I want’

Better leadership from the parts of government most concerned could change these attitudes. An improved level of debate on climate change that puts the effects into a proper context compared to other risks may help to increase the level of understanding.

Customers place a very high value on security of supply. As part of our reporting and monitoring obligations, we conduct meetings and surveys to explain impact of climate change on security and to understand customer willingness to pay within that context. This will help to ensure that our proposed system enhancements are resilient to climate change impacts and acceptable in terms of water charges.

7.2 Regulatory barriers

Regulatory intervention to date has had far more of an impact on customer costs and security of supply issues than the potential impacts of climate change on the business. There is no indication that this will change in future. Regulatory barriers to effective adaptation include:

- Slow provision of suitable incentives for individuals or organisations to change
- Modest coordination and linking of approaches among industry regulators
- Unwillingness to allow investment in resilience and maintenance of ageing assets
- A focus on short term issues to be resolved over 5 years rather than long term solutions
- An approach that discourages research and innovation in the industry
- High aspirations but modest support or leadership to deliver the desired outcomes
- Setting industry requirements that customers perceive as unnecessary or unwanted

Conflicting objectives of regulators and government departments can delay the progress of desirable outcomes. The ‘additionality’ debate in respect of how household water efficiency measures are implemented is an example how a desirable objective can be eclipsed by peripheral considerations.

7.3 Market failure

Increasing the water efficiency of the housing stock would be a minor, but valid adaptation to the impact of climate change. In 2009, the government set out its aspiration for reduction in household consumption in their vision 'Future Water'. These objectives depend on housing developers and manufacturers making changes to the water efficiency of their particular products and planning authorities enforcing these changes. While a small minority have a positive approach to water efficiency, it is clear that little change has occurred and a more proactive approach by government is required to achieve a real market transformation.

7.4 Interdependencies

We are dependant upon other infrastructure and organisations to ensure business continuity, as others may be rely upon our activities. These critical interdependencies are:

- Suppliers of critical treatment chemicals during extreme weather
- Power supply and transmission utilities
- Providers of communication networks and infrastructure
- Owners of other third party assets (flood defences, Sharpness canal and pumps)

A failure in one of these components would have a knock on effect on the secure operation of our business. This would be particularly true for the providers of long-lived assets or structures as detailed in section 4. However, we area aware the organisations concerned have their own plans to maintain resilience as part of their adaptation plans.

We already have formal and informal communications with these organisations and have a close working relationship in most cases. We expect that an ongoing dialogue will ensure that a shared approach to adaptation will enhance resilience.

Section 8. Monitoring and Evaluation

The water industry is regulated and monitored across many areas of business operations. As a part of this regulation, there is a regular regime of reporting in place. The primary regulators in the context of customer service delivery and other outturns are:

- DEFRA
- Ofwat
- Environment Agency
- Drinking Water Inspectorate (DWI)
- Natural England
- Consumer Council for Water

8.1 Monitoring

The monitoring process will be based upon the current suite of regulatory and statutory reporting requirements at various intervals:

Report and analysis every five years include:

- **Strategic Direction Statement (SDS) -All stakeholders**
  Setting out key issues to be addressed in the Ofwat Periodic Review

- **Statutory Water Resources Management Plan (WRMP) –DEFRA, EA**
  Maintaining the long term supply demand balance, deployable output, security of supply, climate change projections, demand forecasts and investment proposals

- **Final Company Business Plan (FBP) -Ofwat**
  Spending proposals over following five years to deliver the SDS and WRMP

Report and analysis every three years include:

- **Statutory Drought Contingency Plan –DEFRA, EA**
  Estimating impact of drought and demand restrictions, monitoring environmental indicators and detailing emergency responses and remedial actions

Report and analysis every two years include:

- **Water Quality Schemes -DWI**
  Progress of on scheme implementation to deliver improved water quality

The annual reports and analysis are:

- **June Return -Ofwat**
  Detailing consumption, security of supply and comparison of outcome against funded Company Business Plan proposals

- **June Return -Environment Agency**
  Monitoring of annual outturns of water demand, deployable output, leakage, water efficiency against those forecast in WRMP and FBP

- **WRMP update – DEFRA**
  Statutory requirement to report compliance with, or material changes to the WRMP

- **Annual Water Quality Return DWI**
  Compliance sampling results for raw and treated water

The monitoring regime is intensive and detailed. It allows a process of almost continual assessment of the company position in respect of the projected planned position. This approach allows new risks and better information be identified and incorporated where appropriate. The long-term plans can be adjusted as needed to ensure they reflect new requirements.

The monitoring process will ensure that the proposals in our plans are delivered, or identify any particular issues affecting delivery of planned outcomes in terms of customer benefit. This frequent analysis will help to define the capital investment and revenue requirements at future AMP periods.

As our approach is modified over time, Ofwat will review our business plans at each quinquennium as part of the Periodic Review and set out in their determination the extent to which customers should fund any identified improvements.

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APPENDICES

Glossary of terms and abbreviations

Abstraction The removal of water from any source, either permanently or temporarily.

Abstraction licence
The authorisation granted by the Environment Agency to allow the removal of water from a source.

ACORN
A Classification Of Residential Neighbourhoods (ACORN) is a socio-demographic classification of neighbourhoods published by CACI Ltd. The system is based on the assumption that people who live in similar neighbourhoods are likely to have similar behavioural and consumption habits.

Allowable outage
The outage (calculated from legitimate unplanned and planned events) which affects the water available for use. An outage allowance may be made for such outages.

Annual average
The total demand in a year, divided by the number of days in the year.

Available headroom
The difference (in Ml/d or percent) between water available for use (including imported water) and demand at any given point in time.

Average day demand in peak week
One seventh of total demand in the peak week in any 12 month accounting period (ADPW).

Average incremental social costs
The ratio of present social costs over present net value of additional water delivered or reduced demand

Baseline forecast
A demand forecast which reflects a company's current demand management policy but which should assume the swiftest possible achievement of the current agreed target for leakage during the forecast duration, as well as implementation of the company water efficiency plan, irrespective of any supply surplus.

Consumption monitor
A sample of properties whose consumption is monitored in order to provide information on the consumption and behaviour of properties served by a company.

Demand management

The implementation of policies or measures which serve to control or influence the consumption or waste of water (this definition can be applied at any point along the chain of supply).

Deployable output
The output of a commissioned source or group of *sources* or of bulk supply as constrained by: environment
• Licence, if applicable
• Pumping plant and/or well/aquifer properties
• raw water mains and/or aquifers
• transfer and/or output main
• treatment
• water quality

Distribution input
The amount of water entering the distribution system at the point of production

Distribution losses
Made up of losses on trunk mains, service reservoirs, distribution mains and communication pipes. Distribution losses are distribution input less water taken

Distribution system operation use (DSOU)
Water knowingly used by a company to meet its statutory obligations particularly those relating to water quality. Examples include mains flushing and air scouring

Drought order
An authorisation granted by the Secretary of State under drought conditions, which imposes restrictions upon the use of water and/or allows for abstraction/impoundment outside the schedule of existing licences on a temporary basis.

Drought permit
An authorisation granted by the Environment Agency under drought conditions, which allows for abstraction/impoundment outside the schedule of existing licences on a temporary basis.

Dry year annual average unrestricted daily demand
The level of demand, which is just equal to the maximum annual average, which can be met at any time during the year without the introduction of demand restrictions. This should be based on a continuation of current demand management policies. The dry year demand should be expressed as the total demand in the year divided by the number of days in the year.

Final planning demand forecast

A demand forecast, which reflects a company's preferred policy for managing demand and resources through the planning period, after taking account of all options through full economic analysis.

Final planning scenario
The scenario of water available for use and final planning demand forecast which constitute the company's best estimate for planning purposes, and which is consistent with information provided to Ofwat for the Periodic Review.

Forecast/plan horizon
The end date of demand forecast or water resources plan (for example, 2035).

Maximum Likelihood Estimation (MLE)
A statistical technique where a reconciliation item is distributed to the largest and least certain components of an estimate of the magnitude of a variable. The technique can be applied to the reconciliation of a water balance.
Meter optants
Properties in which a meter is voluntarily installed at the request of its occupants.

Meter programme Properties, which are to be metered according to current company metering policy.

Micro-component analysis
The process of deriving estimates of future consumption based on expected changes in the individual components of customer use.

Net Present Value
The difference between the discounted sum of all of the benefits arising from a project and the discounted sum of all the costs arising from the project.

Non-households Properties receiving potable supplies that are not occupied as domestic premises, for example, factories, offices and commercial premises.

Normal year annual average daily demand
The total demand in a year with normal or average weather patterns, divided by the number of days in the year.

Outage
A temporary loss of deployable output. (Note that an outage is temporary in the sense that it is retrievable, and therefore deployable output can be recovered. The period of time for recovery is subject to audit and agreement. If an outage lasts longer than 3 months, analysis of the cause of the

problem would be required in order to satisfy the regulating authority of the legitimacy of the outage).

Point of abstraction
The top of a borehole for borehole abstraction; the river intake for a river abstraction to direct supply or bankside storage; the draw-off tower for a direct supply reservoir.

Point of consumption
The point where the supply pipe rises above ground level within the property, usually the inside stopcock or an internal meter.

Point of delivery The point at which water is transferred from mains or pipes, which are vested in the water supplier into, pipes which are the responsibility of the customer. In practice this is usually the outside stopcock, boundary box or external meter.

Point of production
The point where treated water enters the distribution system.

Potable water produced
Raw water treatment less treatment works operational use and treatment work losses

Potable water exported
Potable water exports from within a defined geographical area to an area outside the defined geographical area

Potable water imported
Potable water imports from outside a defined geographical area to the defined geographical area.
Raw water abstracted

Raw water abstracted at the point where abstraction charges are levied. It is made up of raw water retained and raw water exported
.
Raw water collected
Raw water retained plus raw water imported

Raw water Exported
Raw water exported from a specific geographical area

Raw water imported
Raw water imported from outside of a specified Imported geographical area
Raw water losses The net loss of water to the resource system, comprised of mains/aqueduct (pressure system) losses, open

channel/very low pressure system losses, and losses from break-pressure tanks and small reservoirs.

Raw water operational use
Regular washing-out of mains due to sediment build-up and poor quality of source water.

Reconciliation item
The difference between the estimates of the magnitude of a variable and the sum of the estimates of the individual components of that variable.

Resource zone The largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall.

Risk A measure of the probability and magnitude of an event and the consequences of its occurrence.

Source A named input to a resource zone. A multiple well/spring source is a named place where water is abstracted from more than one operational well/spring.

Supply-demand balance
The difference between water available for use (including imported water) and demand at any given point in time (c.f. available headroom).

Supply pipelosses
The sum of underground supply pipe losses and above ground supply pipe losses.

Sustainability reduction
Reductions in deployable output required by the Environment Agency to meet statutory and/or environmental requirements.

Target headroom
The threshold of minimum acceptable headroom, which would trigger the need for water management options to increase water available for use or decrease demand.

Total leakage
The sum of distribution losses arid underground supply pipe Losses.

Total water management
All water management activities from source to end use (i.e. resource management, production management, distribution management and customer-side management).

Treatment work losses
The sum of structural water loss and both continuous and intermittent over-flows

Treatment work operational use
Treatment process water i.e. net loss, which excludes water returned to source water

Underground supply pipe losses
Losses between the point of delivery and the point of consumption

Unrestricted demand
The demand for water when there are no restrictions in place (this definition can be applied at any point along the chain of supply).

Void property A property connected to the distribution network but not charged because it has no occupants.

WRP tables Water resources plan tables used for presenting key quantitative data associated with a water resources plan.

Water available for use
The value calculated by deducting allowable outages and planning allowances from deployable output in a resource zone.

Water delivered
Water delivered to the point of delivery

Water delivered billed
Water delivered less water taken unbilled. It can be split into unmeasured household, measured household, unmeasured non-household and measured non-households water delivered

Water taken
Distribution input minus distribution losses

List of abbreviations

ADPW	Average day demand peak week
AISC	Average incremental social cost
CAMS	Catchment abstraction management strategies
CAPEX	Capital expenditure
CLG	Communities and Local Government department
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of Environment, Transport and the Regions; (now Defra)
DoE	Department of the Environment; (now Defra)
DO	Deployable output
GCM	Global circulation models
Ml/d	Megalitres per day Megalitres = one million litres (1000 cubic metres)
MLE	Maximum Likelihood Estimation
ODPM	Office of the Deputy Prime Minister (now replaced by CLG department).
Ofwat	The Water Services Regulation Authority
ONS	Office for National Statistics
OPEX	Operating expenditure
PCC	Per capita consumption - consumption per head of population
SOA	Super Output Areas
UKCIP	UK Climate Impacts Programme
UKWIR	United Kingdom Water Industry Research Limited
WAFU	Water available for use
WAG	Welsh Assembly Government
WCA	Water Companies Association
WFD	Water Framework Directive
WRMP	Water resources management plan
WSA	Water Services Association
Water UK	Water UK (formerly known as the Water Services Association)